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"The distribution, grades and mineralogical composition of gold-bearing placers in Alberta"

by

Lorenzino Giusti

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

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EDMONTON, ALBERTA

Fall, 1983

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Abstract

This is a study of the occurrence, origin, morphology, geographic variations in the chemistry of gold from placer/sedimentary environments in Alberta. All the literature appertaining to the topic is reviewed and new data regarding the distribution, grades and mineralogical composition are generated.

New mounting and polishing techniques have been tried; they constitute interesting options when dealing with soft metal specimens. More than 4000 grains were observed under a stereomicroscope, 100 were photographed and qualitatively analyzed using a Cambridge 150 SEM, and 653 were studied in detail. They are mainly from the North Saskatchewan River and the Athabasca River. The composition of 553 of these was determined using an ARL-EMX electron microprobe.

Three morphological varieties of gold could be identified: detrital gold (1-5 % of the grains observed), recrystallized gold (about 90 %) and "new gold" and/or gold associated with carbonaceous material. Petrographic and probe studies revealed silver intragrain zoning. The content of this metal is typically low in the outer part of the grains, which results in a high-grade rim (up to 0.100 mm) around the grain core.

There is no increase in the average fineness of the nuclei of the gold grains on going downstream. The average Ag content increases for decreasing size of the grains. The majority of the gold particles from the North Saskatchewan River have a fineness in the range 850-960, the rest are scattered towards lower values, down to 550. In the Athabasca River three main ranges prevailed: 850-950, 760-790 and 625-670.

Flattening increases as the size of the grains decreases except for the smallest fractions (Mesh+230 or smaller): for these the reverse was noticed.

The placer gold is probably Cretaceous in age and derived from sources located in the western mountain range(s) existing at those times.

The pattern of the bedrock channels of Alberta reveals a migration of the river beds during glaciation with consequent deposition of gold in areas now drained by various rivers. Glaciation produced a thick layer of overburden covering possibly richer placers.

The feasibility of exploiting the placer gold deposits of this province is considered. More efficient recovery methods, such as froth flotation, and some changes in the placer mining regulations, are required if gold is to be collected profitably.

Further investigations should be undertaken on platinoids and scheelite in order to understand their significance. More extensive studies are suggested on gold in coal from the Edmonton Formation.

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I. Introduction

A. MINERALOGY AND GEOCHEMISTRY OF GOLD

Mineralogy

In nature, gold occurs mainly as the native metal. Several varieties of native gold are known, for it is always alloyed with other metals such as Ag, Cu, Fe, Rh, Ir, Pt, Pd, Bi, etc.

Gold-mercury amalgam was reported by Palache *et al.* (1944). The composition seems to correspond to the formula Au_3Hg_3, but Foster *et al.* (1977) found a more complex series of Hg-Au alloys to be present as a film coating of placer gold. The most abundant of these alloys were Au_2Hg, $AuHg_2$, but Au_2Hg_3(?), Au_3Hg(?) and Au_5Hg were also noticed.

Atanasov *et al.* (1982) found "white gold" to be represented by three phases: (Au,Hg), Au_3Hg and Au_2Hg.

Other than native gold, there are a few important gold minerals, namely: various tellurides (gold and/or gold-silver tellurides) which frequently also contain Cu, Pb and Sb; calaverite ($AuTe_2$, sylvanite ([Au,Ag]Te_2) and petzite ([Ag_3Au]Te_2). are the most common. Other gold-rich minerals are rare. According to Simons and Prinz (1973), gold occurs in small amounts in sulphide minerals (generally less than 5ppm) and is less than 1ppm in other minerals; thus, it is almost insignificant from a metallurgical point of view. The sulphides are the only exception to this rule, particularly pyrite, chalcopyrite and arsenopyrite. Up to 500ppm (in sulphides) have been reported by Boyle (1979) and Jones and Fleischer (1979).

The gold minerals are listed in table 1, the result of a review of the literature to 1982.

TABLE 1. NATURALLY OCCURRING GOLD-RICH MINERALS

Gold alloys and metallic compounds		
-native gold	Au	Au > 75%
		Ag: 5-15%
		Cu: max. 20.4%
		Fe: max. 0.1%
		Bi: max. 3.0%
		Sn: max. 0.3%
		Pb: max. 0.2%
		Zn: max. 0.8%
		Al: max. 0.002%
-electrum or argentian gold	(Au,Ag)	Au: 45-75%
		Ag>20%
-kustelite or aurian silver	(Ag,Au)	Au< 45%
-porpezite or palladian gold	(Au,Pd)	Pd: 5-10%
-auricupride or cupriauride or cuprian gold	$AuCu_3$	Au 40%
-rhodite or rhodian gold		Rh: 34-43%
-aurosmirid, aurosmiridium, aurian osmiridium or iridic gold	(Au,Ir)	Ir<30%
-gold amalgam	Au_2Hg_3	Au: 34.2-41.6%
-maldonite or bismuthic gold	Au_2Bi	Au: 64.5-65.1%

		Bi: 35.5%
-palladium cuproauride	$(Cu,Pd)_3Au_2$	Au:<67.4%
		Rh, Ag, Bi, Ni: tr.
Antimonides		
-aurostibite	$AuSb_2$	Au: 43.5-50.9%
Sulphides		
-uytenbogaardite	Ag_3AuS_2	Au: 33.7%
Selenides		
-fischesserite	Ag_3AuSe_2	Au: 29.0%
Tellurates		
-gold-tellurate(?)		
Tellurides		
-krennerite	Au_4AgTe_{10}	Au: 30.7-43.9%
-calaverite	$AuTe_2$	Au: 39.2-42.8%
-sylvanite	$AuAgTe_4$	Au: 24.25-29.9%
-kostovite	$CuAuTe_4$	Au: 25.2%
-petzite	Ag_3AuTe_2	Au: 19.0-25.2%
-hessite	Ag_2Te	Au<4.7%
-montbrayite	Au_2Te_3	Au: 38.6-44.3%
-nagyagite	$Au(Pb,Sb,Fe)_8(S,Te)_{11}$	Au: 7.4-10.2%
-muthmannite	$(Ag,Au)Te$	Au: 22.9-31.0%

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1. Sources: Palache et al (1944)
Terziev (1966)
Jones and Fleischer (1969)
Henley (1975)
Boyle (1979)

2. Many other auricuprides are mentioned in the literature, such as $CuAu_{3-4}$, CuAu, $CuAu_{4}$, etc.

3. There is a complete substitutional series from native gold to silver.

4. Other Hg-Au alloys have been reported: $Au_{2}Hg$, $AuHg_{2}$, $Au_{3}Hg$, $Au_{5}Hg$.

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mullerite = krennerite
speculite = krennerite
silberphyllinglanz = nagyagite
blatterine = nagyagite
goldschmidtite = sylvanite
coolgardite = mixture of calaverite, coloradoite and sylvanite
antamorite = mixture of petzite and altaite

Geochemistry of gold

Gold is a member of group I B (Au, Cu, Ag) of the periodic system. It has 3 main valencies (oxidation states), namely: 0 (native), +1 (aurous), +3 (auric). Other pertinent physicochemical properties are:

Atomic number: 79
Atomic weight: 196.967
Specific gravity: 19.32 (pure gold) at 20°C
Melting point : 1063.0°C (1,945°F)
Electronegativity: 2.3-2.4
Atomic radius: 1.40 A°(8), 1.44 A°(12).

It has high ionization and oxidation-reduction potentials. Thus it occurs chiefly as a native element. It is a low-volatile metal, but in the presence of chlorine it may form highly-volatile compounds. A continuous series (though discontinuous in nature) of alloys are possible with Ag due to their identical atomic radii, and to a lesser extent with Cu (atomic radius: 1.28 A°).

In natural conditions, native gold may contain various amounts of many other elements, such as: Fe, Pt, Pd, Zn, Al, Bi, Sn, Hg, etc. Gold has an affinity for tellurium (Te), bismuth (Bi) and antimony (Sb).

The most common ions Au^{+1} and Au^{+3} have a high oxidation potential and therefore are not stable in water; but in aqueous solutions gold tends to form complex compounds, such as $[Au(CN)_2]^-$, $[AuCl_2]^-$, $[AuS]^-$, $[AuSb]^{2-}$, $[Au(AsS_3)]^{2-}$, etc. The possibility of transportation of ionic gold in nature has been overestimated in the past. According to Goni *et al.* (1967) gold solutions are very unstable and quickly decomposed in the acid conditions of natural waters or in the oxidation zone of ore deposits, especially when the environments are rich in sulfur. Under ionic or metallic conditions, gold can easily form colloids, which allows the gold to migrate for long distances in suspension.

In nature there are at least 70 elements more abundant than gold whose abundance in the Earth's crust is between 0.003 and 0.004 ppm, that is approximately 1 gram per 300 metric tons (Li and Yio, 1966; Jones, 1968; Lee and Yao, 1970). In the upper lithosphere it shows a strong siderophile character, occuring predominantly in the native state, as natural alloys (containing mainly Ag, Cu and platinoid metals) and as a trace element in other native metals and semi-metals (Fe, Cu, As). It is also combined with tellurium, bismuth and antimony. It is weakly chalcophile (only one natural gold sulfide is known, namely: uytenborgaardite, Ag_3AuS_2) and is not oxyphile. No natural gold silicates have been found. Gold is present as traces in coals , petroleum and oil shales, indicating the ability of organics to adsorb gold complexes from solutions.

The presence of a trend in gold contents in the various rock families is still uncertain and there are many controversial data on the matter so that it is difficult to generalize, but many authors seem to agree on many points. Gold seems to be usually more abundant in sedimentary rocks (especially in sandstones and conglomerates) than in igneous rocks and, among the latter, it is higher in mafic than in felsic rocks (Shcherbakov and Perezhogin (1964).

Gold deposits themselves, however, are more often associated with felsic or intermediate igneous rocks than with mafic or ultramafic types, or with the more siliceous or aluminous sedimentary or metamorphic rocks (Simons and Prinz, 1973). According to Shcherbakov and Perezhogin (1964) the average gold content decreases from meteorites to ultramafic, mafic and felsic rocks, from extrusive to intrusive and from ferromagnesian silicates to feldspars. They found a direct correlation between the content of gold in intrusive rocks and their Fe, Mg, Cu and V contents. They thought the chance of chemical bonding of gold in silicates (which is low) decreases as their structures change from nesosilicates to tectosilicates, so that in the sequence ultrabasic-basic-intermediate-acidic rocks, gold is increasingly removed, accumulated in the fluid phases and concentrated during the last stages of crystallization. This would explain why gold mineralization is more commonly associated with felsic rocks although the mafic rocks are the main carriers of the metal. The main auriferous provinces of the world, excluding the auriferous gabbroic and ultramafic intrusives, would be, according to them, regions of granitoid intrusions into rocks locally enriched in gold, from which they inherited the metals (already present).

Moiseenko and Fatyanov (1972), in summarizing the geochemistry of gold, maintain that gold originates in basic and ultrabasic magmatic suites. Granitization, metamorphism and disintegration of those rocks cause the release of the metal, which is then transferred to melts, solutions and weathered rocks.

Hydrothermal gold deposits are formed within the temperature range of 30° to 430°C; the early stages, which occur at high temperatures (230-430°C) are barren or slightly auriferous; the productive stages occur within the interval 130°-200°C. The hydrothermal solutions of this latter stage are apparently alkalic-bicarbonatic in composition, chlorine is always present and Na prevails over K. Gold transportation in hydrothermal soution occurs chiefly as sodium chloride- and thiosulfate-complexes. This contradicts the idea that the fineness of gold depends upon the temperature of ore formation. Coefficients relating the gold fineness to the chlorine content and the sum of the alkalies have been established.

It would appear that metamorphism effectively flushes silver out of electrum-type alloys and the gold becomes finer in rocks of higher grades of metamorphism.

The average gold content in ultramafic rocks seems to be around 0.004 ppm; 0.007 ppm in basic rocks, 0.005 ppm in intermediate rocks and 0.003 ppm in acid rocks.

In sedimentary rocks the averages are as follows:

0.03 ppm in sandstones and conglomerates,
0.004 ppm in shales, argillites, mudstones, etc.,
0.02 ppm in evaporites,
0.015 ppm in black shales, sulphidic schists, pyritic tuffs, etc.

In sedimentary rocks there seems to be a close association of gold with carbonaceous material, in many respects similar to the relationship existing between organic matter and uranium.

In metamorphic rocks the average content is usually higher in quartzites (0.005 ppm), greenstones (0.004 ppm), skarns (0.008 ppm) and lower for other types.

Certain sandstones and conglomerates, graphitic shales, sulphide schists, may contain up to 4 ppm of gold.

In metamorphic rocks, gold occurs preferentially in pyrite, pyrrhotite, arsenopyrite, other sulphides and mafic minerals and is particularly enriched in skarns and other veins formed during the late stages of high-grade metamorphism and granitization.

The average gold content of soils is about 0.005 ppm; it is 0.00003 ppm in natural fresh waters and 0.000012 ppm in sea and ocean waters. Coal ashes contain up to 0.1 ppm Au. Plants and animals contain gold in traces.

Pyrite and other sulphides are common associates of gold minerals. Therefore, rocks containing high concentrations of pyrite, chalcopyrite, pyrrhotite, arsenopyrite and other sulphides are usually enriched in gold.

Types of gold deposits

Gold occurs in a wide variety of primary and secondary deposits and as a trace in other ore types. According to Simons and Printz (1973) these deposits can be grouped into seven broad categories:

1. **Gold-quartz lodes.** They are mainly hydrothermal veins of quartz and gold, which replace wall-rock or fill dilatent spaces along fractures. They were formed at great depth, enclosed in Precambrian rocks and of Precambrian age. They are usually metamorphosed volcanic and sedimentary rocks of the greenstone-granite association.

   The gold content of such ores when mined is 0.3-0.6 ounces per ton. These account for about 20-25% of the World's output. However, the trend is downward from these figures.
2. **Epithermal ("Bonanza") deposits.** They are represented by hydrothermal veins of quartz, carbonates, barite, and fluorite, containing native gold or gold tellurides and variable but commonly large amounts of silver relative to gold. They are typically present in altered volcanics of Tertiary age,

where they fill open spaces. They were formed within a depth of hundreds of metres, seldom more than 1km. They show an extremely variable content of gold, which is usually more than that of the gold-quartz lodes, mainly in the range 0.5-1.0 ounce per ton of ore. They account for a very small fraction of the world's gold production because most of the potential deposits have probably already been exploited. They were easy to discover, more so than the other kinds of gold deposits.

3. **Young placers.** They are associated with unconsolidated or semiconsolidated sand and gravel. Their contribution to total World production has declined during the last decades. It used to be around 2/3, then 1/3 ,and it is probably now less than 1/4 due to exhaustion, environmental problems and to increasing costs of operation.

   Placer deposits are still playing an important role in the U.S.S.R. where placer operations yield a significant fraction of the production of the country.

   A very rich placer would contain a few grams per ton of Au but it is usually less, down to 0.1 ppm.

4. **Ancient (Fossil) placers.** These are of Precambrian age and have been lithified to conglomerates. The average grade of gold ranges from 0.2 to 0.8 ounces per ton. The main example is the Witwatersrand district of South Africa which dominated the gold production for about thirty years. Similar deposits are present in other Archean-Lower Proterozoic shield areas.

5. **Marine placers.** This gold is derived either from land and carried to the ocean by rivers or from the reworking of rocks of the sea floor. The largest known gold-bearing area on the sea floor is in the Northern Bering Sea with concentrations ranging around 30-100 ppb.

6. **Deposits of disseminated gold.** These consist of very fine-grained gold, disseminated in silty and carbonaceous dolomitic limestone due to hydrothermal replacement of the host rock (e.g., The Carlin Deposit in

Nevada and the Kuranak Deposit in Siberia). They probably represent former hot-spring sites.

7. **Byproduct gold.** Gold is present as a minor constituent of many base metal ores; in particular copper ores or complex ores of lead, zinc and copper. The grade of gold is generally <1 ppm, ranging around 0.04–0.9 ppm, (that is 0.001–0.025 ounces per ton). Despite these low concentrations, the production of gold from such deposits accounts for 5 to 10 % of total World output due to the large tonnages of base metal ores mined.

Gold metallogenetic epochs

During the geological history of the Earth, certain intervals of time seem to have been particularly favourable for the generation of epigenetic gold mineralization and also for the formation of gold placers.
The preferential concentration of gold deposits in Precambrian times is probably only apparent, due to the enormous span of time elapsed during this first part of the Earth history, which was characterized by many orogeneses, perhaps more than those of subsequent epochs. The main characteristics of the gold metallogenetic epochs in North America are summarized below.

1. PRECAMBRIAN. Auriferous deposits occur mainly in the Canadian Shield and in the Black Hills of South Dakota. They are deposits of the gold-quartz type and disseminated type within ancient volcanics (greenstones) and associated sediments and volcanoclastics.
   Platinum metals are not present except as traces.
   The most important gold deposits in the Canadian Shield were generated during the Archean Kenoran orogeny (2500 m.y.). In the Superior and Slave structural provinces, where the Archean rocks are best preserved, they consist of intrusives, acidic to basic in composition, and volcanic flows, interbedded and/or overlain mainly by greywackes, together constituting the typical greenstone belt.

   > "The Archean rocks contained enough gold and other metals to be the source of all the epigenetic deposits found within these" (Boyle, 1976).

   The average Au/Ag ratio of these quartzose ores is about 8.

2. PALEOZOIC. There are no epigenetic gold deposits known to be associated with the orogenesis which took place in Paleozoic times in the Cordillera of North America.

3. MESOZOIC. The Cordilleran region was marked, during this Era, by two main orogenies:

1. The Columbian or Nevadan Orogeny (Late Jurassic to Early Cretaceous),
2. The Laramide Orogeny (Late Cretaceous to Early Tertiary).

Gold-quartz type deposits prevail, but polymetallic- and skarn-type deposits are also widespread.

The most famous Cenozoic placers of British Columbia, Yukon, Alaska and California were derived from Mesozoic deposits.

The gold is present as the native metal, as gold-silver tellurides, or associated with pyrite and arsenopyrite.

The Au/Ag ratio varies from 9 to 5.

4. CENOZOIC. Intrusions of granitic-monzonitic rocks and porphyries were emplaced into the preexisting rocks of the Cordillera, accompanied and followed by intense diastrophism (uplift, faulting, warping) and volcanic activity of mainly andesitic and rhyolitic character. The low content of gold of this volcanic material suggests an older source for the precious metal: Boyle (1979) thought that they could be tuffs and sediments of Tertiary age or older sediments of the carbonaceous pyritic variety.

   The gold is generally free or associated with the sulphosalts and extremely fine grained.

   The average Au/Ag ratio is about 10 but it can be as high as 40.

B. GOLD DEPOSITS IN WESTERN CANADA

Gold deposits in British Columbia and Yukon

Some 35.0 million ounces of gold have been produced in Western Canada up to the end of 1978; 47% from placer mining, mainly in the Cariboo and Klondike districts, 42.4% from lode gold and the remaining 10.6% as biproducts from base metal mines. Placer gold production dominated the period 1858–1917, lode gold from 1918 to 1967 and by-product gold from base metal deposits prevailed in the production of the last 15 years.

The Western Cordillera has been subdivided into 5 main tectonic belts, namely: Insular, Coast, Intermontane, Omineca and Eastern Belts (Wheeler, 1970). Most of the production came from placer deposits and mines in the Intermontane and Omineca Belts. The most important mining camps (Fig. 1) were: Rossland, Hedley, Bridge River, Premier and Barkerville (Cariboo). The lode gold of these areas is typically present in quartz veins occurring in faults cutting volcanic and sedimentary rocks of mainly Mesozoic age (usually eugeosynclinal or arc-type sedimentary and volcanic rocks adjacent to intrusives of varying composition). Earlier gold-bearing protoliths may have provided gold, which was remobilized and reconcentrated into these younger veins. Native gold, electrum, tellurides, arsenopyrite, pyrite, chalcopyrite, galena, sphalerite, pyrrhotite and scheelite are the main metalliferous minerals of these veins.

The first gold rush followed the discovery of rich placer deposits (Fig. 3) along the Fraser and Thompson rivers, about 120 years ago. Another main gold rush was the result of the discovery of the Klondike placers, in the Yukon, at the end of the nineteenth century. The Cariboo (Barkerville) district lies within the Intermontane plateau region. The bedrock is essentially composed of folded and faulted sedimentary strata of the Lower Paleozoic Cariboo Group which hosts numerous stringers and veins, plus replacement bodies (in the limestones). Gold mineralization occurred between the Carboniferous and Early Tertiary and postdates the formation of the quartz veins (Sutherland Brown, 1957). The source of the gold in the placers is not known with certainty.

Placer gold does not show, as a rule, a greater fineness than the lode gold (Johnston and Uglow, 1926). The fineness was in the range 775–950 for the former, and 850–910 for the latter. Gold-rich rims were present on the nuggets, due, according to the investigators, to leaching of silver. Johnston and Uglow concluded that most of the gold was detrital and partially a result of accretion processes in the gravels.

According to Boyle (1979, p. 357), in Tertiary times, during a gradual uplift, extensive gold-bearing gravel accumulated in river valleys covered in Pleistocene time by stagnant ice-masses which acted as protective coverings preventing scouring and dissipation. Gold placers formed during interstadial periods, from gravels reworked by the rivers and by meltwater. The Klondike district lies within the Omineca Belt. The bedrock is essentially composed of Klondike Schist which is probably of sedimentary origin and Precambrian or Early Paleozoic in age. The gold deposited in the preglacial White Channel Gravels originated from the numerous small, narrow, discontinous veins and lenses occurring in the schist. These were eroded in Early Tertiary times, during weathering under moderate to semi-tropical conditions.

Aggradation prevailed in the Late Tertiary and the gold was redistributed in the alluvium, well below the level of the White Channel Gravels. The Western Yukon escaped glaciation, therefore the gold-bearing deposits were not destroyed. The fineness of the placer gold is variable, even in the same creek, due to the different grade of the lode gold from which it was eroded; it ranges from a minimum of 625 to a maximum of 890.

According to McConnel (1907) some of the gold is high grade, as the surficial layers of the nuggets were subjected to the leaching of silver. Spectrographic analyses of gold from many creeks of the district, always show Ag, Cu, Hg, Ti, Mg, Al and Fe to be present. Traces of Pb, As, Sb, V, Ba and Sn were also detected in some cases.

In B.C. there are many other districts famous for their placer deposits, namely: the Atlin District, the Cassiar District and the Princeton District. In the Atlin district, a plateau deeply eroded and modified by glaciation is underlain mainly by sedimentary, volcanic and intrusive rocks Precambrian to Pleistocene in age (Aitken, 1959). The placers are present in an area containing base-metal sulphide deposits and gold-bearing quartz veins. Similar placers are present in the Cassiar District, mainly along the following rivers: the Dease, Thibert, McDame and Goldpan (Hanson and Mc Naughton, 1936; Gabrielse *et al.*, 1962). In the Princeton District of southern British Columbia, the bedrock is composed of sedimentary rocks interbedded with Paleozoic to Late Tertiary volcanics, plus intrusive rocks ranging in composition from granite to peridotite and in age from Jurassic to Late Cretaceous or Early Tertiary (Camsell, 1913; Rice, 1960; Raicevic and Cabri, 1976).

The most famous placers are those of the Similkameen and Tulameen rivers, where gold and platinoid minerals are present in a ratio of about 4 to 1 in the Similkameen River and in the lower reaches of the Tulameen River, decreasing upstream to a point where platinoids equal or exceed the amount of gold. The platinoid minerals are mainly isoferroplatinum, native platinum, ferroan platinum, tulameenite, iridosmine, osmium and rutheniridosmine. The gold occurs in rough nuggets (flour gold is comparatively scarce). The platinum is present as small rounded grains, smaller than the gold nuggets on average. The original source of gold and platinum in the placer deposits is believed to be (Rice, 1960) the gold-bearing veins of Grasshopper Mountain and environs and the Olivine Mountain body of platinum-bearing ultrabasic rocks.

Small examples of eluvial placers are known in Canada, mainly in the Yukon. In the Dublin Gulch area, Yukon (Boyle, 1965a), they are present on the sides of the hills above the economic gold placer in the gulch. The principal heavy minerals in the eluvium are gold, scheelite, wolframite, hematite nodules (of iron-formation), garnet, cassiterite, magnetite, pyrite, arsenopyrite, etc. The first three minerals were derived from scheelite-bearing skarn, quartz-wolframite veins and from quartz-arsenopyrite-pyrite-scorodite-gold veins, all lying slightly uphill from the eluvial placers. The eluvial material containing gold and scheelite is greatly enriched in As, Sb, and W.

As far as the ore controls are concerned, Barr (1978) suggested several regional and local guides which are useful in the exploration for gold within the domain of the Canadian Cordillera:

1. Both placer and lode deposits are spatially related and are localized in eugeosynclinal environments at or near the margins of the main crystalline belts.
2. Gold seems to be associated with intrusive complexes ranging from plugs to stocks, acid to ultrabasic in composition.
3. The gold deposits occur mainly in Upper Triassic to Lower Jurassic Rocks.
4. Mineralization follows the faults patterns. This is true also for replacement as they are usually localized where fractures prepared the way for alteration and replacement.
5. Most of the gold mines are present within strongly folded sequences, in which orebodies occur on subsidiary flexures or drag folds within the folded formations.
6. The minerals which commonly accompany gold in lode deposits are: pyrite, pyrrhotite, arsenopyrite, sphalerite, chalcopyrite and galena.

An epigenetic origin for the lode deposits was largely accepted in the past but new genetic theories seem to gather more and more consensus. Many geologists propose a primary volcanogenic origin, followed by deformation, recrystallization and remobilization. Three main populations of gold deposits are present in the Cordillera if the quantities of ore milled from the principal mines are plotted against the ounces of gold produced:

1. Lode gold mines with an average grade of 0.4 oz/ton
2. Pyrometasomatic and volcanogenic deposits with an average grade of 0.05 oz/ton
3. Sulphide replacement and Co-Mo porphyries with an average grade of 0.005 oz/ton

Many new gold and/or silver deposits have been recently discovered in B.C. (Schroeter, 1981). They quite often exhibit features which are typical of similar deposits in Nevada, Colorado and Mexico. They are considered geothermal (epithermal) and volcanogenic in origin; the most important of them are the Toodoggone District, Capoose Prospect, Equity Silver Mine, Big Missouri–Premier Deposits, the Dolly Varden–Torbrit Deposits. The Toodoggone Deposit lies within the eastern margin of the Intermontane Belt; the volcanic rocks of the area seem to be related to dykes emanating from the granodioritic–quartz monzonitic intrusions of the Omineca Batholith. The Geological Survey of Canada obtained a K/Ag age of 186–200 my (Jurassic to Cretaceous) for those plutonic rocks. The mineralizing solutions followed the channelways provided by intense normal faulting during the span going from Jurassic to Tertiary. The paragenesis, which is typical of the Omineca Batholith, shows that gold and silver are present as biproducts in a porphyry copper deposit in which base metals are prevalent. In the epithermal mineralization base-metal (Cu, Pb, Zn) are also present but Au and Ag prevail as fine grained acantite, electrum, native gold and silver (Ag:Au=25:1). Base metals were deposited earlier than precious metals.

The Capoose Prospect is mainly a deposit of silver and base-metals. Again, a magmatic source is postulated to have produced heat and the mineralizing solutions.

The Equity Silver Mine contains a Cu–Ag–Au–Sb, high-level, volcanogenic deposit; stockworks, disseminations and volcaniclastic sedimentary rocks of Middle to Upper Mesozoic age. The age of the associated intrusions seems to be , from K–Ar dating, around 56 my.

A syngenetic, epithermal mineralization, related to volcanism, is postulated for the Big Missouri deposit; Au and Ag prevail over base metals.

At the Premier deposit, mineralized veins in a cataclasite zone adjacent to the Texas Creek Pluton show a high concentration of silver and gold (25:1) and lead–zinc biproducts.

At Dolly Varden–Torbrit no gold is present, whereas good grades of silver and lead are typical.

In the Yukon the main gold–silver deposits are epithermal (veins and disseminations), mesothermal (veins and mantos), and contact skarns. The epithermal mineralization occurs in the central and western Yukon, associated with hypabyssal and subaerial felsic volcanic rocks of the Late Cretaceous to Early Tertiary age Mt Nansen Group (Morin, 1981), the hypabissal volcanics providing the heat source.

If the Au/Ag ratio of samples from various deposits (in Yukon) is plotted versus the sum of base. metals, three main trends prevail (Fig. 2):

1. High Au/Ag, low base metal.
2. Low Au/Ag, high base metal.
3. Low Au/Ag, low base metal.

The epithermal deposits pertain to all three groups whereas the mesothermal are concentrated in the area of the diagram showing high Au/Ag, low base metal content. This is probably related to the comparatively more uniform composition of mesothermal veins originated in a more stable environment.

The element zonation is typical of epithermal deposits with Au (As, Sb, etc.) increasing and Ag (Zn, Pb, Cd, etc.) decreasing towards the top of the veins. In epithermal conditions the fluid composition changes quickly in response to physical and chemical variations. It has also been observed that where gold decreases silver and base metal contents increase.

Gold deposits in Alberta

Small quantities of placer gold have been recovered annually in Alberta, especially along the North Saskatchewan River, since at least, 1859, when James Hector (Hector, 1861) saw :

"...a few specimens of gold washed out."

In 1891 the occurrence of platinum was first recorded by Hoffman :

> "Native platinum has been found, in association with gold, on the bars in the North Saskatchewan River, in the neighbourhood of Edmonton, district of Alberta, North-West Territory. A sample of the material from this locality, received from Mr. William Pearce, consisted of exceedingly minute, rounded and flattened grains of native platinum, the largest not exceeding one-fourth of a millimetre in diameter, with intermixed, equally minute scales of native gold. Mr. Johnston found a certain proportion, about one-fourth, of the platinum to be magnetic. No evidence could be obtained of the presence of iridosmine in the particular sample examined" (Hoffman, 1890-1).

The origin of these precious metals has been a matter of dispute for many years; it is not clear whether the gold and platinum have been carried by the rivers flowing eastward from the Cordillera, where it was originally associated with intrusions, contact aureoles or with hydrothermal veins, or whether Precambrian rocks of the Canadian Shield to the north-east supplied the placer detritus.

In 1861 Hector stated:

> "There is no trace on that side (eastern) of the axis (of the Rocky Mountains) of the ancient rocks from which it (the gold) must have been derived."

In 1873, the Director of the Geological Survey of Canada, A.R.C. Selwyn, referring to the gold of the North Saskatchewan River, wrote that there were no obvious mother lodes at the source of the river. Both Selwyn (1873-4; 1875-6) and Dawson (1895) suggested that the Precambrian rocks now comprising the glacial drift were the original source of the gold. These authors thought the gold could have been washed out of the Pleistocene till mantle covering the Prairies. In particular, in his Annual Report for 1873-4, Selwyn stated:

> "...along with the disappearance in ascending the river, of the boulders of granitic, gneissic and other crystalline rocks, the auriferous character of the drift likewise dies out."

He found no gold upstream from Rocky Mountain House, and observed that the gravels were all derived from the mountains further west of that locality.

Tyrrel (1886; 1915), Taylor (1934) and Rutherford (1937) favoured, though via different arguments, the possible origin of the placer gold in a source located to the west.

Tyrrel (1915) postulated that the gold came from erosion of the sandstones of the Upper Cretaceous Edmonton Formation which, in turn, were derived from bedrocks in the mountains west of the Upper Columbia Valley. More precisely, the gold was found to be apparently more abundant where the North Saskatchewan river was underlain by the Cretaceous , coal-bearing rocks of the Edmonton Formation. He pointed out that the composition of the Edmonton Formation

> "... was not such as might have been derived from the degradation of the quartzite, slates and limestones of the Rocky Mountains, but that the material of which the sandstones especially were composed, was such as might be expected to be derived from the degradation of granitoid rocks."

In other words the Edmonton Formation was composed of material which would have been deposited into the Cretaceous Albertan Sea before the onset of the Laramide orogeny and therefore before the uplift of the Rocky Mountains. The present day river would have merely *reconcentrated* gold of a low-grade placer deposit originally located west of the Upper Columbia Valley.

Taylor (1934) however, found no gold in the arenaceous beds of the quartzite gravel lying directly upon the erosion surface of the Edmonton Formation. This gravel is considered to be derived from Tertiary conglomerates which once covered the Edmonton District (relicts now cap the Cypress and Hand Hills). Those clastics were laid down by ancient rivers flowing from the Rockies.

Rutherford (1937) postulated that the gold was derived mainly from the erosion of the Edmonton and Paskapoo Formations. He wrote that the composition of the Saskatchewan gravels and sands

> "...might be suggestive of material derived from Cordilleran glaciation but the shape of the pebbles does not indicate such a source, unless they were subsequently well sorted and transported long distances."

In places where sand prevailed, the gold content was found to be higher. As far as the coarse clasts of the gravel beds are concerned, they were found to be of two types:

1. Bedrock fragments of local derivation,
2. Pebbles or boulders derived from the west, but not from beds as highly metamorphosed as the most easterly Precambrian strata in Jasper National Park; namely: chert, dark-red arkoses, quartzitic sandstones and arkosic sandstones.

> "Saskatchewan gravels and sands are well exposed in the cut banks along the Saskatchewan River above, within, and below the limits of the city of Edmonton. The exposures, especially those above the city, are predominantly sand with relatively little gravel and the basal zones of the sands at or near bedrock carry fine gold, especially where

> such contacts are relatively low in the river valley" (Rutherford, op. cit.).

Cooke and Johnston (1932) in their summary account of the gold occurrences in Alberta wrote:

> "All the gold is fine and is found associated with coarse gravels on such bars as are uncovered at low water. There is no concentration of gold on bedrock. The pay-gravels are only a few inches to a few feet thick and occur only on bars where conditions are favorable for the concentration of gold by alternate deposition and erosion by stream action. In places the bars are overlain by a considerable thickness of barren alluvium. The gold is derived from sedimentary formations, of Upper Cretaceous or early Tertiary age, through which the valley of the streams have been eroded; it has been reconcentrated from ancient low-grade placers. The gold extends up the river from Edmonton for about 50 miles or somewhat more, and downstream nearly to Battleford, but the most productive areas were in the stretch extending for 15 or 20 miles above and below Edmonton ."

Allan (1919) mentioned that the North Saskatchewan, Peace and possibly the Liard Rivers all contained significant placer gold; moreover, tributary streams of the Athabasca River had been found to contain placer gold and some platinum.

> "The gold is irregularly distributed throughout the gravels, and along old river channels. Concentration has taken place in the most protected portion of the stream channels. The gold is extremely fine in texture and flaky. It is frequently called flour gold, but under a microscope the flakes are usually well rounded. Platinum and iridium are frequently present as minute silvery grey, flattened grains."

Platinum was recovered in 1917-18 in the gravels on the North Saskatchewan between Clover Bar and Fort Saskatchewan. He added:

> "Information to date would seem to indicate that certain Peace River placers are richer in platinum than those of North Saskatchewan."

In the first annual report on the mineral resources of Alberta, he concluded that:

> "At least part of the gold is derived from the glacial and glacio-lacustrine deposits which cover most of the surface of the pre-Cambrian areas to the north-east."

He also mentions that 'reef gold' was known to occur from samples in the Precambrian rocks north of Lake Athabasca and also north of Great Slave Lake, (i.e., Goldfields, Saskatchewan and Yellowknife, N.W.Territories, respectively).

According to Boyle (1979)

> "...most of the gold in the North Saskatchewan River is present as very minute flakes and pellets in coarse gravel on the top few inches

> or few feet of the bars in the river all the way from Rocky Mountain House to Prince Albert, a distance of some 500 mi. or more. The richest parts begin near Goose encampment, where the big coal seam at the top of the Cretaceous Edmonton Formation crosses the river, continues past Edmonton and ceases in the vicinity of Beaver Lake Creek. Throughout the whole of this distance the coal-bearing Edmonton Formation forms the banks of the North Saskatchewan Valley"

and

> "it seems probable that the coal-bearing parts of the Edmonton Formation are indeed the source of the gold since pyrite is common in these rocks, and pyrite in coal is commonly slightly auriferous."

Another theory has been proposed by La Casse (1982, personal communication). According to La Casse the gold's origin might have been in the range of mountains which would have existed where the Foothills are now located. This would imply a revision of at least part of the stratigraphy of the area. An interesting point is that gold lodes are present in the Rocky Mountains of Alberta and these were actually mined up until the 1930's. The exact locations are mentioned by La Casse and J. Roebuck in "Minerals of Alberta" (1978). La Casse grew up in what is now the Banff National Park and had the chance to know personally the miners of the area. The last of them, Joseph Smith continued work until 1937 when he retired at the age of 94.

The recovery of gold in Alberta

Small amounts of placer gold have been recovered intermittently from the North Saskatchewan River since, at least, 1887.

Tyrrel (1915) wrote that almost 30,000 oz. of gold had been washed from the North Saskatchewan River in the period going from the middle of the 19th century (1859) to the year of publication of his work.

The Department of Mines of Canada had previously published data on alluvial gold recovered from the N. Saskathewan River for the period 1887-1912 (26 years) and Tyrrel assumed, on the basis of the fact that gold had been mined since 1861, when the river bars were richer and relatively undepleted, that at least the same amount of gold was recovered during the earlier 26 years.

Table 84 and Fig. 46 show the production of gold in Alberta since 1887. The sources of information were:

1. Dominion Bureau of Statistics Reports (1887 to 1948)
2. Canadian Mineral Yearbook (1962 to 1978)
3. Canadian Mineral Industry (1953 to 1961)
4. Western Miner (June 1982, p. 12)
5. Mineral Production of Canada (1928).

Therefore, the total amount of gold recovered is, officially, until 1981, some 31,788 oz. or about 989 kilograms; it does not include the gold collected by occasional prospectors -nd snipers, quite numerous in Alberta, who punctually pan and sluice [1] along the rivers when the level of the water is low enough. No individual reports are usually received from prospectors and production credited as to placer mining is obtained from Government mints statements.

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[1] Sluicing requires a special placer mining permit issued, under certain conditions, by the Mineral Resources Division of the Department of Energy and Natural Resources.

Gold was collected also from other rivers, such as the McLeod River, the Athabasca River and the Peace River but no data are available.

After the publication of the report on Tyrrel's investigation, the placer miners concentrated their attention on the exploration of the sand bars in areas where the Edmonton Formation outcrops, so that in 1896 the production rose considerably (2661 oz. or 82.777 kgm.).

The (official) production reached its maximum in 1980 (4276 oz.; 133.016 kgm.) following the upward trend of the gold price.

Table 85 and the accompanying graph (Fig. 47) report the price of gold during the period 1887-1981. Data were obtained from the following sources:

1. Engineering and Mining Journal (March 1982)
2. Metals week (1980)
3. Engelhard Industries Quotations (1947 to 1979).

Fig. 48 shows the London gold prices with the monthly average. The price was $US 20.67 per fine troy ounce until 1933. In 1935, the official price of gold, established under authority of the Gold Reserve Act (January 31, 1934) was fixed at $US 35.00 per fine troy ounce. After 1967 the price was allowed to fluctuate and the general trend was towards higher values with the main exception of 1976 in which a 22 % drop occurred. The main reasons have been: rapid inflation, oil prices, poor returns on other investments, political tensions.

The upward trend came to an end during the course of 1981 when, due to a rapid escalation of interest rates, it reached its lowest level of $US 296.75 in June 1982.

A drop in interest rates caused a reverse trend, and gold reached a high of $US 488 in September 1982.

In 1983 the gold price will probably reach again the $US 650 (Bosh, 1982), unless the market is not able to absorb substantial Russian and OPEC members sales which are likely to characterize the supply for a long period of time.

Systematic prospecting was conducted in Alberta by Halferdahl (1965), under the auspices of the Alberta Research Council, in order to determine the extent of possible payable ground. Fig. 49 shows the localities which have been sampled, and the following is a part of the open file report:

> "The places sampled were systematically, but fairly widely distributed (20 miles or more) along the rivers. The results showed that all the gold passed a 35 mesh screen and may be described as 'flour gold'. The highest concentrations were found along the North Saskatchewan River in the stretch from Devon (about 25 miles upstream from Edmonton) to near a point due north of Myriam (about 150 miles downstream from Edmonton). Few, if any, concentrations found during the survey would be considered high enough for economic recovery. The survey was designed to locate areas worthy of detailed sampling. However, the fine nature of the gold and the fact that such gold does not concentrate in paystreaks on bedrock, as shown by drilling conducted here and there by various people during the past half or three-quarters of a century, indicated that more detailed sampling was not worthwhile at present. Prospecting and testing in the stretch of river mentioned above are required to learn whether high concentrations of sufficient yardage are present for economic recovery. The chances are not particularly promising, because the gold is so fine grained that the concentrations are not expected to be high enough to make a small operation worthwhile, and the yardage is not expected to be great enough for a large operation."

Several cubic feet of gravel were sieved and panned for each locality. The quantity of gold recovered from each sample, subdivided into size-fractions, is reported in Figures 50 to 61. These results have been utilized here to plot a series of diagrams (Figures 63 to 71) in which the quantity of gold recovered is plotted against the distance from the provincial boundary or from the mouth (in miles along the river). In some cases, 2 samples were collected at the same locality (or quite close to each other) so that two symbols are indicated for the same sampling area. A star represent the total amount of gold recovered, a square indicates, for the same locality, the amount of gold finer than Mesh+120.

It is quite evident that only the N. Saskatchewan River, the McLeod and possibly a few localities along the Red Deer River and Milk River show interesting figures. For example, at Location 118 the gold concentration reaches 247.200 mg/cu yd and if we consider that fraction M-120 constitutes about 70-80 % of the gold recovered, we can assume that even higher grades would be possible to obtain if a more efficient recovery method could be used. From the plot in Fig. 72 we can deduce that only about 50 % of the gold of this size can be recovered , at the most, using proper mechanical devices.

The main method used today is gravity concentration using sluices. Sluice-boxes are utilized in many gravel pits across Alberta and by occasional prospectors; many of these sluices are quite inefficient (Romaniuk, 1981) and they almost invariably lose all the gold finer than 100 micrometers (0.100 mm) in size, due to low shape factors of the flakes, porosity (pores may be filled with low-density minerals which reduce the specific gravity of the gold) and gold surface hydrophobicity.

Fig. 72 shows the efficiency of various gravity devices in recovering gold particles of different sizes (Wang, 1979).

Fig. 73 shows the relationship between gold-particle size and flotation recovery. The advantages are:

1. a very high efficiency
2. less environmental problems
3. a cleaner concentrate suitable for direct smelting.

If this method is used in Alberta, the recovery of gold would be certainly feasible, in particular if associated with simultaneous gravel pit operations (on Saskatchewan sand and gravel)

Operations of this kind could start in Alberta only if the placer mining regulations were changed.

Gold in the Precambrian of Alberta

Rocks of the Precambrian age are exposed in north-eastern Alberta for about 8,000 square miles; in the National Parks of the Rocky Mountains, sedimentary and volcanic strata of Precambrian age have been thrust up by late Mesozoic faulting (Burwash, 1951).

Athabasca Oil Limited, in 1912, drilled a well on the east bank of the Athabasca River approximately 20 miles below Fort McKay. The depth of the contact between the sedimentary formations and the Precambrian was 1105 feet. A gold assay of $13 per ton was reported for the rock on the contact (Allan, 1929).

II. SAMPLING

A. REPORT ON THE OCCURENCE OF GOLD AND PLATINUM IN PLACER DEPOSITS IN ALBERTA

The field survey portion of this study was conducted utilizing mechanical sluicing of sand and gravel in most of the major rivers of Alberta, in particular, the North Saskatchewan River, the Athabasca River, the Peace River, some of their tributaries, other minor rivers and, less extensively, the Red Deer River and the Battle River.

Samples were collected, when possible, where natural concentrations of precious metals were more likely to occur, that is, at the junctions of tributaries, the insides of meander bends, point bars, or where the river currents slowed for some reason (e.g., natural riffles, obstructions, etc.). Some samples could not be obtained due to lack of time and funds and quite often owing to the presence of "No Trespassing" signs which hindered sampling in areas that could otherwise have been very good for the purpose of this research. Such signs are prevalent on cultivated fields on old river beds and terraces and access to the river is thus very difficult.

The highest concentrations of gold grains were found along the North Saskatchewan River, the Athabasca River and the Redwater River. Some of these areas should be sampled in more detail, as should the old river benches of the Peace River. The quantity of material washed at each location was minimal, but sufficient to constitute a reasonable data-base for the assessment of the behaviour of gold in many of the drainage channels.

The sluice box

The sluice box used during this study was a two-piece unit with zig-zag design riffles (Plate 1.1). The two identical boxes were constructed of fibreglass. The boxes are 4 feet long, 18 inches wide and 8 inches deep at the head, 16 inches wide and 6 inches deep at the issue end. The apertures (one at the bottom end of the first, upper, box and one at the front end on the second), are 14 inches wide (= 35.56 cm). A plastic hose with two series of holes for a spray-jet water input is present at the head of the sluice. Water is supplied to the sluice using a centrifugal pump with the following characteristics:

Type: self-priming TAS portable 1ngine Pump.
Maker: TANAKA KOGYO Co., LTD.
Model: QCP-12S.
Max. output volume: 120 L/Min.
Weight: 6.0 Kgs. (13.2 Lbs.)
Fuel: mixed fuel of gasoline and 2 cycle special oil at T% 1.

A grizzly set-up was constructed at the head of the sluice. In the first box there is also a riffle area with a riffle arrangement composed of sections of 1" angle aluminum; some of these being common riffles (Hungarian type), some of the zig-zag type, and others of the Chevron type. Under the riffle system there is an expanded aluminum mesh, with the incline running lengthwise, and an outdoor carpet below. The bottom of the second box contains another riffle arrangement with the same assortment of riffles which can be adjusted in different ways by screws.

The two boxes can be fixed to a series of two-piece support legs in aluminum, and can be assembled in such a manner as to resemble a closed box (Plate 1.2); all the hardware and tools can thus be stored inside and the whole unit can be easily carried and stored. The type of construction material used, namely fibreglass, has many advantages:

- relatively light weight
- relatively low cost
- no rust
- elasticity
- no absorption of "fines" by the material
- no joints are present between side and bottom boards, thus no "fines" are

lost.

The zig-zag type of sluice has some advantages as it slows down the speed of the water and the drops between the boxes give the clay "pellets" more chance to be broken up and to release the gold they may contain.

Since gold in Alberta is essentially flour gold (usually less than 800 micrometers in diameter) it would be better to have as many boxes as possible. At least 3 or 4 boxes would be ideal, as it takes a considerable length to trap the fines, especially when there is a high content of clay. The first (top) box should be used only as an input box so that the material may be more efficiently washed, without affecting the proper deposition of heavy concentrates lower down the system. However, this is contrary to the placer mining regulations of this Province.

Sluicing

Sand and gravel were introduced into the head of the sluice by means of a shovel, puddled against the flow of the water so that large stones and pebbles were forked out only when clean. It is very important (i) to avoid fluctuations in feeding the sluice box, (ii) to find out the best grade at which the boxes have to be set (the incline or descent is usually 8 - 18 inches per 12 feet), and the optimun water flow.

S.V. Griffith, (Alluvial Prospecting and Mining, 1960) wrote:

> "The ideal to aim at in sluicing is the keeping of a thin layer of sand constantly passing over the riffles, so that any heavy mineral particles, such as gold or tin, etc., in the feed can sink through and come to rest behind the riffles, where they are caught. Should it so happen, however, that the riffles are covered with packed sand, i.e. sand not in motion, the heavy mineral particles, not being able to sink through to the bottom of the sluice box, will come to rest there and will remain there so long as the packed sand is not disturbed.
> If, now, the density of the feed to the sluice box becomes intermittent, or is altered so that the solids entering the box are diminished, the excess water, having less sand load to carry, will start scouring away tha packed sand together with any heavy mineral particles it may contain, with the result that heavy losses may occur. This can be obviated by the employment of wider and shallower boxes, as the sand load will then be spread over the entire width of the sluice box in thinner layers, so affording greater ease of

penetration to the heavy mineral content."

It is easy to find the best gradient with which to work when the material is sand or loose gravel. Serious problems arise when treating clayey material for even a good flow of water cannot disintegrate the small "pellets" which get washed out together with the small quantity of gold that they may contain. On the other hand, if the energy of the water flow is too high, some of these "pellets" break down, but the heavy concentrates do not settle. Moreover, a grizzly placed at the head of the sluice will not help, for when the material collected is sticky, it does not drop into the box unless a lot of work is done to disintegrate the pellets and to bring water through an additional hose or via a pail. However, flushing with buckets of water may be dangerous as undesirable intermittent feed is caused.

Many of the rivers where samples were taken, often had a high percentage of silt and clay - the water levels were still high due to the extreme runoff - and this resulted in some waste of time in determining the optimum velocity of the water flow, and much work had to be done to disintegrate the "pellets". This is one of main reasons, why the material processed was probably in many cases insufficient to provide reliable data concerning the economic viability of the gravels studied. The efficiency of the sluice is increased if the oversize and worthless material is washed and screened out prior to sluicing.

At least 24 hours are necessary to sluice properly (utilizing the two-piece sluice box) one cubic yard, with a water input around 10-13 gallons/min. (about 1 miner's inch). When the material was clayey or contained a large proportion of gravel, a greater water-flow was necessary or it necessitated an adjustment of the grade of the two boxes. After trials, the grizzly was used at the end of the first box (upside down) acting as a screen in such a manner as to collect pellets of clay and gravel, which had a better chance to be broken and cleaned, respectively. Once in a while the grizzly was taken away in order to clean out the accumulated gravel.

When gold is present, even with a good inclination of the boxes, some particles still existed in the tailings lounder. Especially with greasy water, as noticed by La Casse and Roebuck (Gold Panning Guide, 1980), some gold seems to float because it is trapped by grease particles or because surface tension is involved. This is the case of the Saskatchewan River for example. Another pertinent observation, is the tendency of the majority of the grains of gold to act as the larger grains of sand during their deposition - this is in accordance with Orest Romaniuk's work (Gold of the Saskatchewan Sands and Gravels, 1981). The studied gold is associated with a matrix essentially composed of sand or sand and some gravel, with pebbles less than 3-4 centimetres across. When the majority of the matrix is composed of pebbles and cobbles the concentration of gold seems to decrease in the area. Sometimes it was concentrated in the sand around and under large boulders (and of course in the sand of uprooted trees or moss). Probably where pebbles and cobbles prevail, the current energy is too powerful even for heavy concentrates.

Robert Peele (Mining Engineers' Handbook, 1950) gives the following data on the moving power of water in rivers and creeks, supposing that no riffles exist:

1. 0.25 ft per sec. begins to wear away fine sand.
2. 0.50 ft per sec. just lifts fine sand.
3. 0.66 ft per sec. carries fine sand.
4. 1.00 ft per sec. moves fine gravel.
5. 2.00 ft per sec. moves pebbles of 1 inch diameter.
6. 3.00 ft per sec. moves pebbles of egg size.
7. 5.33 ft per sec. moves stones, 3 - 4 inch diameter.
8. 6.66 ft per sec. moves stones, 6 - 8 inch diameter.
9. 10.00 ft per sec. moves stones, 12 - 18 inch diameter.

It is felt that only the first 5 situations can be conducive to the accumulation of gold and platinum and in particular the fourth one.

Location of samples

River and number (Fig. 4)

Athabasca 1 (Fort McMurray)
Athabasca 2 (Athabasca)
Athabasca 3 (Smith)
Athabasca 4 (Fort Assiniboine)
Athabasca 5 (Blue Ridge)
Athabasca 6 (Jasper)
Athabasca 7 (Athabasca Falls)
Battle 8 (Mc Laughlin)
Freeman 9 (Mouth)
Hay 10 (MacKenzie Highway)
Hangingstone 11 (Gregoire Lake)
Little Smoky 12 (Highway 43)
Little Smoky 13 (Guy)
North Saskatchewan 14 (Waskatenau)
North Saskatchewan 15 (Victoria SMT.)
North Saskatchewan 16 (Shandro)
North Saskatchewan 17 (Fort Island)
North Saskatchewan 18 (Cabin Lake)
North Saskatchewan 19 (Rocky Mountain House A)
North Saskatchewan 20 (Rocky Mountain House B)
North Saskatchewan 21 (Drayton Valley)
North Saskatchewan 22 (Berrymoor)
North Saskatchewan 23 (Devon A)
North Saskatchewan 24 (Devon B)
North Saskatchewan 25 (High Level Bridge)

North Saskatchewan 26 (Murphy Park)

North Saskatchewan 27 (Murphy Park A)

North Saskatchewan 28 (Murphy Park B)

Peace 29 (Peace Municipal District)

Peace 30 (Fort Vermilion)

Peace 31 (Mushikitee Island)

Peace 32 (Dunvegan)

Redwater 33 (Redwater)

Smoky 34 (Bezanson)

Vermilion 35 (Mouth)

Wapiti 39 (Grovedale)

Pembina 36 (Dapp)

Ponton 37 (Rocky Lane)

Red Deer 38 (Emerson Bridge)

Whitemud 40 (Improvement District 22)

Wild Hay 41 (Highway 40)

Details of location and brief descriptions of samples

1 - Fort McMurray.

West bank of the river, about 100 metres downstream from bridge, just in front of the large island bar which is at the confluence of the Clearwater River with the Athabasca River.

2 cubic feet of sand and gravel were sluiced and the concentrate panned.

Some colors of gold were noticed.

2 - Athabasca.

North bank of the river on sand bar exactly under the bridge and 10-20 metres downstream.

3 cubic feet of sand and gravel were washed.

A lot of black sand is visible and many colors of gold, especially when the material processed is sandy. In contrast, almost nothing is present when there is a high percentage of clay.

The opposite bank of the river was checked but only a small quantity of black sand was separable and no visible gold in the pan.

This is probably because gold tends to take the shortest route as it is carried downstream, so it gathers on the insides of bends. In other cases this rule did not work and more gold was noticed on the *wrong* side of the river, but it was probably so-called *moss gold*.

3 - Smith.

South bank of the river, under the bridge, on sand bar and nearby bench.

1 cubic foot of sand from the sand bar, plus 1 cubic foot of the superficial layer of the nearby bench (rich in moss); the black sand and gold come essentially from this latter superficial part of the sample.

4 - Fort Assiniboine.

South bank of the river, under the bridge. This sample was not calibrated and it came from a few panfuls. The material is very fine-grained, essentially clay.

There is no black sand, no visible gold.

5 - Blue Ridge.

North bank, about 40 metres upstream from the bridge, 5 km before Blue Ridge.

2 cubic feet of sand, clay and gravel. Some black sand is present and good colors of gold, some of them coarser than the usual flour size.

On the opposite side of the river the material is different and no gold is present in it; the sand and gravel picked up in a pit on the bench have a very low content in black sand and no visible gold.

6 - Jasper.

West bank, about 1.5 km before the junction to Maligne Lake.

About 1 cubic foot of clay and sand: no gold.

7 - Athabasca Falls.

Highway 93, South of Athabasca Falls. East side of the river.

About 1 cubic foot of material.

No gold.

8 - Mc Laughlin.

North bank of the river, under the bridge, (Road 17) before the junction with Highway 14.

The material, 1 cubic foot, is essentially clay, plus sand and some fine grained gravel.

No gold is visible.

9 - Freeman.

East bank, about 10 metres upstream from the mouth.

A few shovelfuls of sand were panned, there is a very low percentage of black sand. No gold.

10 - McKenzie Highway.

West bank of the river, about 10 km after Meander River, coming from High Level (McKenzie Highway).

1 cubic foot of material (mainly clay, plus a minor percentage of sand and gravel) was panned.

There is just a small amount of black sand. No gold.

11 - Gregoire Lake.

West bank, about 20 metres downstream from the bridge on Highway 63.

1 cubic of sand, gravel and clay.

A lot of black sand and just a few colors of gold.

12 - Highway 43.

West bank of the river, under the bridge (Highway 43), at the town of Little Smoky.

2 cubic feet of clay, sand and gravel.

There is some black sand containing very fine-grained gold.

13 - Guy.

(a) East bank of the river, and (b) downstream end of two island bars, 30 metres and 15 metres from East bank, respectively; about 1 km downstream from the bridge, 10 km before Guy (Highway 34).

2 cubic feet of sand.

More black sand is present at site (a), less at site (b); a few very fine grains of gold.

14 - Waskatenau.

North bank, about 50 metres upstream from the bridge (Secondary Road 831).

The sand bar was very small due to the high level of the water.

4 cubic feet were washed: 1 cubic foot from the river bench and 3 cubic feet from the sand bar.

Black sand and gold are present.

During panning very fine, flat particles of gold were noticed.

15 - Victoria Settlement

North bank, 5.4 km upstream from bridge (Road 855).

4 cubic feet of sand: (a) 2 cubic feet from sand bar (small, due to the high level of the water), and (b) 2 cubic feet from river bench - both (a) and (b) contain gold .

16 - Shandro.

South bank, about 200 metres downstream from the bridge.

2 cubic feet of sand and gravel. Gold is present in the black sand.

17 - Fort Island.

North bank, 500 metres downstream from the bridge, 2 miles from Fort Island.

3 cubic feet of sand and gravel.

Some gold.

18 - Cabin Lake.

South bank, exactly under the bridge.

2 cubic feet of sand, clay and pebbles.

Some gold.

19 - Rocky Mountain House (A).

South bank, 20 metres upstream from the bridge.

2 cubic feet of clay and sand plus some gravel.

Very little black sand and fine grained gold.

20 - Rocky Mountain House (B).

Downstream end of island bar, 10 metres from West bank, about 800 metres downstream from site of sample 19 and upstream from the bridge (Highway 11).

2 cubic feet of material have been processed: it is essentially sand, containing some black sand and some gold.

There is an outcrop of coal at left bank. Pieces of coal are present in the sand bars downstream from this point mixed with sand and gravel (at least up to Devon).

It is very rich in pyrite; some specimens have been collected and will be assayed for gold.

21 - Drayton Valley.

Sand bar, 100 metres from West bank of the river.

1 cubic foot of material was washed, about 10 metres upstream from the bridge: it is essentially sand. There is some black sand but no visible gold.

22 - Berrymoor.

South bank, about 1 km downstream from Berrymoor ferry (bridge under construction).

2 cubic feet of material: (a) 1/2 cubic foot of sand of the bank, 50 metres upstream from site (b); (b) 1 cubic foot coming from the sand of an uprooted trees along the bank; and (c) 1/2 cubic foot from the bed of the river about 300 metres downstream from site (a).

Here (c) the river bend has its maximun curvature.

The maximun quantity of black sand and gold comes from spot (b), less from site (a) and almost nothing from site (c).

23 - Devon (A).

South bank, on sand bar about 500 metres downstream from bridge.

1 cubic foot of sand and clay plus some gravel.

Some black sand is present and gold too, especially *moss gold* .

24 - Devon (B).

North bank, on bar and river bed about 300 metres upstream from bridge.

Good black sand and good colors of gold; a few platinum grains.

Not calibrated.

25 - High Level Bridge.

South bank on sand bar about 50 metres downstream from High Level Bridge.

Some black sand and gold are present.

Not calibrated.

26 - Emily Murphy Park. Edmonton.

South bank, on bar starting at groat bridge.

18 cubic feet of sand and gravel, from different points along the bar, were washed and the concentrates panned.

Very good colors.

27 - Emily Murphy Park. Edmonton.

The specimen was previously collected along the same bar of locality 26, and donated by La Casse.

28 - Emily Murphy Park. Edmonton.

The gold grains were separated from sample 26 on the basis of their distinctive colour and morphology. A sample of similar material was donated courtesy of La Casse.

29 - Peace Municipal District.

Not calibrated.

NW bank, on bar about 15 km from Peace River, nearby Road 684.

No, or very little, black sand. No visible gold.

This situation was noticed along all the stretch from Peace River to the Peace Municipal District, that is for about 25 km; here the river does not show a meandering pattern.

30 - Fort Vermilion.

South bank, on sand bar and bank about 30 metres upstream from the bridge.

2 cubic feet of sand and clay (about 50%).

There is no or very little black sand, no visible gold.

31 - Mushikitee Island.

NW bank. The material (2 cubic feet of sand) has been collected at different sites along the bank, just in front of Mushikitee Island.

There is a cart track leading to the spot, about 1 km before the ferry.

Some black sand is present. No gold.

32 - Dunvegan.

Sand bar, 100 metres from North bank, and river bed, about 700 metres upstream from the bridge.

In 1.5 cubic feet of of sand, very little black sand was noticed.

No gold.

33 - Redwater.

West (SW) bank, about 100 upstream from mouth.

2 cubic feet of sand and clay.

Black sand and gold are present.

34 - Bezanson.

River bed 25 metres from West bank, about 700 metres downstream from the bridge.

1 cubic foot of sand.

Some black sand is present but no gold and platinum are visible.

35 - Mouth.

Mouth of the river, on West bank.

2 cubic feet of clay and sand plus some gravel.

Black sand and gold are present.

36 - Dapp.

West bank of the river, under the bridge.

1 cubic foot of material, essentially clay and a little bit of sand (about 5%).

Very low percentage of black sand. A few very fine grained particles of gold.

37 - Rocky Lane.

West bank and river bed, about 20 metres downstream from the bridge.

1 cubic foot.

In both types of material there is a good quantity of black sand. Some gold (?) seems to be present.

38 - Emerson Bridge.

South bank, 10 metres upstream from the bridge (Emerson Bridge).

1 cubic foot.

The sand from the bar and the bench does not show much black sand or visible gold.

39 - Grovedale.

Downstream end of island bar, just in middle of the river, and sand bar on South bank, both about 600 metres downstream from the bridge on Highway 40.

1 cubic foot.

No black sand or very little. No gold.

40 - Improvement District 22.

West side of island bar, about 100 metres downstream from the bridge (Road 743).

Some panfuls of sand. No gold.

41 - Highway 40

West bank of the river, about 150 metres downstream from the bridge on Road 40.

There is a car track leading to the spot, on the left side of Road 40 coming from Muskeg River and going to Entrance.

1 cubic foot of sand.

There is just a small amount of black sand. No gold.

III. LABORATORY EXAMINATION

A. SPECIMEN PREPARATION

Specimen mounting

The following are the procedures used in the difficult operation of mounting the grains:

METHOD 1.

The gold flakes were mounted (one by one) by placing each grain standing on its edge on double-stick "Scotch tape"; the tape was previously attached to the top surface of an epoxy base having parallel smooth (polished) surfaces. A few drops of epoxy were gently laid down over each grain until the entire tape strip was covered by epoxy (Fig. 5A to 5F).

The mount was placed into a rubber mould after smearing (spraying) its cavity with glycerine or another release agent; finally, more resin was poured onto the mount in order to obtain a layer of about 0.5 cm thick on top of the tape (Fig. 5G).

METHOD 2.

The sticky tape was attached to a thin plastic support which, in turn, was fixed to a convenient metal disc or glass plate (Fig. 6). The grains were carefully placed on top of the sticky tape, standing on their edge. Each grain was covered with drops of epoxy. A plastic ring was then put on the sticky tape, thus encircling the area clustered with grains, and more resin was poured. The epoxy was allowed to dry overnight and, afterwards, the sticky tape was peeled from the ring and solidified epoxy (Fig. 7). Some glue from the tape usually remains and should be removed using a cotton ball and acetone or ethanol before grinding and polishing, otherwise the mount should be immersed into an appropriate solution which neutralizes the glue so that it becomes very easy to get rid of it by gently rubbing the surface with a wet swab of cotton.

METHOD 3

The procedure is identical to the previous one except that a copper die (parallelepiped) was put on the tape and the flakes were stood leaning against the copper, at the same time touching the tape (Fig. 8A to 8C). Each grain was then covered with epoxy drops and, after putting the plastic ring on the tape, as much resin as necessary to reach the top of the copper die was poured into the assembly (Fig. 8D).

This method was devised in order to prepare mounts for electrolytic and electromechanical polishing. The copper die acts, at the same time, as a support for the gold grains and as a conductor so that the specimens become part of an electrical circuit.

It is clearly very important to avoid formation of bubbles around the grains, particularly between the copper and the grains themselves, because the contact with the die may then be affected.

The exact proportion of components must be mixed when preparing a bath of epoxy. Epoxy resin was preferred for the preparation of the grain mounts because, when cured, it adheres very well to the surface of the grains and it is not as brittle as other resins. 10 parts (by weight) of Araldite Resin 502 were mixed to 1 part (by weight) of Araldite Hardener 956. The mixture was poured into the moulds and let dry overnight at room temperature. Curing at higher temperatures results in poor adhesive qualities and changes in heat-sensitive minerals. Stirring must be gentle and for a couple of minutes. It is advisable to wait for about 10 minutes before using the resin: there will be less bubbles. Neatness and cleanliness at every step are absolute prerequisites for getting good results.

If bubbles are present around the grains (or at the same level of the grains) they must be worked out using a needle, under a good stereomicroscope.

Advantages and disadvantages of the foregoing procedures.

The main disadvantage of method 1 is the fact that the tape remains embedded into the mount so that particular care has to be exercised when grinding and polishing to avoid reaching the level of the tape. The tape strip must be exactly parallel to the top and bottom surfaces of the mount, otherwise during grinding and/or polishing, a portion (e.g.: an edge) of the tape might be exposed and consequently the mount would be spoiled; it is sometimes possible to rescue it by getting rid of the exposed tape (with a needle) and pouring a new, very thin layer of epoxy. Therefore, frequent checks of the mount are necessary, particularly during grinding and rough polishing. This procedure has the advantage that grains as small as 50 micrometres (0.05 mm.) in size can be mounted and polished.

No tape strip remains in the mount using method 2 so that the grains can be ground and polished as much as required without running the risk of exposing the sticky tape. However, problems arise when mounting grains smaller than about 100 micrometres (0.1 mm.) because the surface of the solidified epoxy will show the irregularities originally present on the sticky side of the tape together with a very thin layer of glue: it is then necessary to grind too deeply and the small grains are lost.

With procedure 3 it is very easy to keep the grains erect due to the presence of the copper wall; moreover it is possible to apply electrolytic and electromechanical polishing/etching techniques, because the gold grains become conductive. The copper surface is larger than the surface of the gold grains (Fig. 8E), therefore the current used may be enough for the gold and too much for the copper or vice versa, so that one of the two metals is preferentially polished or etched. Since the copper surface usually deepens more quickly, a problem may arise when it reaches the level where the gold grains touch the copper, thus interrupting the conduction of current and consequently the application of electrolytic or electromechanical polishing (Fig. 8F).

Grinding

The best way to obtain a flat surface of the mounted specimen is to use abrasive paper instead of loose abrasive on steel laps; the specimen can be seriously damaged mainly because loose abrasives easily become embedded so deeply that they cannot be removed by any washing or cleaning process. The tendency for abrasive particles to embed is very serious when dealing with very soft materials such as gold. The problem is less serious when abrasive paper is used (the abrasive particles are here cemented by resin). Emery paper should be avoided; waterproofed alumina papers (Samuel, 1967) seem to be more satisfactory than the corresponding silicon carbide papers since the alumina particles fracture less than silicon carbide particles. The finer grades are more liable to fracture due [illegible] their needle-like shape whereas the coarser grades produce less extensive embedding. Embedding is reduced when abrasive papers are flooded with water which acts as a lubricant and is almost completely eliminated when a soft solid lubricant is used (solid soap, waxes, etc.)

Four types of abrasive papers (240-, 320-, 400- and 600- grit silicon carbide) were used, the first three with only the purpose of reducing the thickness of the epoxy layer covering the specimens and to flatten the surface accurately. The last one (600-) was used to cut the gold grains at sufficient depth to expose their cores (Fig. 8G).

The surface of a mount was ground by holding it and pushing it across the paper with constant, very low pressure; the section was also frequently rotated a quarter turn, washed in running water and dried before going to a finer abrasive paper (the silicon carbide papers were placed on a rotating brass plate, flooded with water during grinding).

The soft metals have a high tendency toward surface flow. Therefore precautions must be taken to avoid excessive pressure, otherwise the original structure of the metal will be obliterated; stubborn, deep-seated scratches may also result and it is sometimes impossible to get rid of these by polishing: specimens which have been properly prepared during the early stages will be free of bad scratches.

After grinding, each mount was carefully washed with lukewarm water, then cleaned with ethanol (methyl alcohol) and dried with a portable hair drier-heater. If this is not done, polishing will remove the embedded fragments of abrasive particles, but they will remain in the polishing cloth (pad) and can cause disastrous damage to the specimen.

Mechanical polishing

The grains were cut with diamond pastes (0.006-, 0.003-, 0.001- and 0.00025- mm.) on a microcloth (Buehler Polishing Cloth, catalog No. 40-7218). The extender used was Buehler Metadi Fluid No. 40-6032. Linde B was tried for the final polishing but it produced a pitted surface so that 0.00025 mm. diamond paste was preferred instead.

Fast polishing rates and flatter surfaces are obtained with hard napless cloths which, however, produce heavily damaged surfaces; softer long-napped cloths are thus preferred. The polishing rate falls off quickly with coarse grained abrasives - so that wear-resistant cloths are required at this stage but the degree of deterioration decreases with fine grained abrasives and the polish is of higher quality. Synthetic suedes made of rayon fibres bonded to a cotton backing have proved to give the best results.

Upon certain conditions of rotational speed and load, the polishing rate is inversely proportional to specimen area, and it is also reduced when the embedding plastic has lower polishing rate than the specimen. The grains of gold were mounted in epoxy which has a polishing rate at least 5 times higher than gold and the exposed area of the gold grains was really very small.

It is good practice to apply interstage cleaning and drying: after washing under a stream of water, acetone or ethanol should be sprayed onto the surface with a squeeze bottle and a very gentle rubbing of the surface with a wet cotton ball is also important. Ultrasonic cleaning, for only a few minutes, is recommended for final cleaning. Drying should be done under a stream of air after flooding the surface with ethanol.

Hand polishing gave better results than automatic polishing on a rotating lap because it was possible to avoid embedding abrasive particles (by applying an appropriate pressure on the mount) and to get rid of, or at least reduce, the number of deep scratches. It is, however, a time consuming method and causes a certain degree of relief, although this may be acceptable.

Electrolytic polishing (Electropolishing)

The metal to be polished forms the anode in an electrolytic cell (Fig. 9) where it is progressively dissolved in such a manner as to remove its irregularities. Electrolytic polishing is particularly effective in brightening the surface of the metal, that is in removing the small-scale, submicroscopic irregularities (down to 0.01 micrometers in size); it is not so effective in performing the smoothing (flattening) function, that is the removal of coarser irregularities (above a micrometer in size) because the rate of removal is usually on the order of 1 micrometer/min. and the metal is therefore dissolved very slowly.

Two processes have been proposed to explain the mechanism of electropolishing:

1. The formation of a thick viscous layer of reaction products around the anode, controlling the smoothing action;
2. The formation of a thin film on the surface of the anode, controlling the brightening action.

The polishing time generally decreases with increasing fineness of initial finish, therefore if the initial finish is coarse, the time necessary to obtain smoothing is too long and the amount of metal dissolved is excessive. The quantity of metal removed is a very important factor when the specimen is very small, as in the case of very fine grained gold flakes. To reduce the time of treatment, the preparation of the surface is one of the most important requirements, together with other factors such as the current passing through the solution, the kind of solution used and the size of the electropolishing system. Stirring is necessary to avoid the accumulation of reaction products around the electrodes, otherwise the viscous layer varies in thickness with consequent inhomogeneous polishing. A uniform cell temperature is also obtained by stirring the solution. Excessive stirring, on the other hand, should be avoided because it could destroy the viscous layer. The anode may be stationary or moving: in the second case a higher current is required to maintain the viscous layer.

Electropolishing was performed on a stainless steel cathode at a cell potential between 8 - 10 Vdc, at room temperature, using the electrolyte reported by Glenn and Raley (1962), and by Redpath and Joshi (1971): it consists of chromium trioxide (15 gm), glacial acetic acid (75 ml) and distilled water (3 ml), heated for one hour at 65°C.

The best polishing conditions are difficult to determine, in particular because the current density depends on sample size. The gold grains, before electropolishing, had just been ground on water-washed 600- grit abrasive paper. After polishing, the mount was immersed in acetic acid, rinsed in distilled water and dried. Electropolishing gave good results with the coarsest (size fraction: +120) grains in about 10 - 15 minutes. The technique tends instead to damage the smaller fractions. This is probably due to the many requirements which must be satisfied in order to obtain the optimum performance of an electropolishing cell, namely (Tegart, 1959):

1. The anode connection should be made of corrosion-resistant material and constructed so that the specimen may be easily and quickly removed from the cell for washing.
2. The current must be switched on before the specimen is immersed in the electrolyte (so that the potential difference required for polishing already exists) and switched off only after the specimen has been removed for washing.
3. Only the portion of the specimen to be polished should be in contact with the electrolyte.
4. The position of the specimen, with respect to the cathode, should remain fixed during electrolysis, so that no unnecessary variation of the internal resistance of the cell occurs.
5. The cathode should be placed so that the gas evolved will not destroy the viscous layer at the anode. The cathode should be as large as possible so that the material deposited on it will be sparsely distributed and the chance of particles leaving the cathode and interfering with the polishing process is very low.

6. Agitation of the electrolyte during polishing, by stirring or by rotation of the anode and/or cathode.
7. The temperature should be kept constant.
8. The cathode should not react with the electrolyte.

Electromechanical polishing

Electromechanical polishing is a technique in which a DC voltage is applied to a specimen which is, at the same time, abraded on a polishing wheel where a cloth is kept wet with an abrasive-electrolyte slurry (Fig. 10).

The optimum current density depends on many factors, namely: type and concentration of abrasive, pressure applied to a specimen, type of polishing cloth, specimen area, etc.; the quality of the polishing depends on the foregoing factors plus speed of rotation, time, polarity, etc. Normal polarity was found to be good for gold-silver alloys. A low-voltage DC power supply is necessary but only a high-voltage power pack was available, therefore the scale was in Amperes and it was difficult to estimate accurately the best current densities. Nevertheless it seems the maximum power supply should be less than 3 Amperes at about 2 - 10 volts. As a general rule (Samuels, 1967), the current density is considered to be too low when the edges of the specimen are properly polished but the centre is etched, and it is indicated to be too high when the reverse occurs. Within this constraint, the current density should be as high as possible in order to obtain the best results.

A conventional polishing machine was modified. A stainless disc was made and inserted into a plastic bowl: it was used as an electrode (cathode) and, at the same time, as a polishing wheel. A polishing cloth was fixed over the disc and the specimen was made the anode. The specimens were ground through 600-grit silicon carbide paper lubricated with water.

a) The abrasive-electrolyte slurry (which is good for both polishing and etching) had the following composition (Piotrowski and Accinno, 1977): 300 cm^3 of 1% NaOH solution mixed with 200 cm^3 of Linde B.

The polishing rate obtained with alumina decreases with increasing pH of the slurry and staining may result when the pH is not in the range 6-7. Electromechanical polishing produced smooth surfaces, free from disturbed layers, almost completely scratch-free, in about 15 - 30 minutes (depending on the speed of rotation and the current applied). Original inclusions were retained after this kind of treatment. Operating conditions were: 0 - 2 A (usually 1 A), about 3 volts and a speed varying from 125 to 250 r.p.m.
Grains of alumina powder tend to get embedded, therefore, after polishing, an ultrasonic bath of 5 minutes was necessary to get rid of these impurities.

b) The solution proposed by H.E.N. Stone (1978) was also tried. Mechanical abrasion was brought about only by the cloth, since abrasives were not added. The mounts were ground again on 600- grit paper, washed, dried and electrically connected to a power pack. The electrolyte was a solution containing 12% sodium thiosulphate and 19% potassium thiocyanate. This electrolyte polishes gold and silver at 70 mA and copper at 30 mA; this means that when polishing the gold grains, the copper surface is progressively corroded also, due to the presence of thiocyanate in the solution.
Platinum grains cannot be mounted together with gold grains because polishing of the former starts, with this kind of solution, at about 600 mA.

The speed of rotation of the polishing bowl was kept around 125 - 200 r.p.m.

Electromechanical polishing was found to be the best technique for polishing soft metals.

IV. MORPHOLOGY, MINERALOGY AND COMPOSITION OF NATIVE GOLD FROM PLACER DEPOSITS IN ALBERTA

A. MORPHOLOGY

Four rivers were selected for mineragraphic study, due to the availability of a large number of gold grains to obtain statistically reliable data. The results concerning the gold from the North Saskatchewan River, in particular, are considered to be representative of the different populations of grains present in the sand bars.

A total number of 653 grains have been studied: 500 from the North Saskatchewan River, 100 from the Athabasca River, 33 from the Redwater River and 20 from the Vermilion River; all of them were first examined megascopically.

58 grains from the North Saskatchewan River were observed, qualitatively analyzed and photographed using the SEM (Cambridge Stereoscan 150) of the Department of Entomology (U. of A.); the remaining 442, classified by size (Table 2), were mounted one by one in epoxy resin, polished, studied under a reflective-light microscope and investigated quantitatively by wavelength-dispersive analysis (WDA). The analysis was carried out using the ARL-EMX electron microprobe of the Department of Geology.

Also 100 grains from four different localities along the Athabasca River (Table 4) were studied, and for 86 of them quantitative electron probe analysis was performed after accurate petrographic investigation.

13 grains from the Redwater River (Table 6) and 12 from the Vermilion River (Table 8) were also analyzed quantitatively.

The grains chosen from the Redwater River concentrates were only a few but they are representative, at least, of the morphology, texture and colour of other 220 grains collected at the same site (Locality 33).

Other heavy minerals were noticed to be present in the concentrates, mainly magnetite, garnet, zircon, pyrite, platinum and scheelite. Magnetite, garnet and zircon were particularly abundant in the concentrates from the North

Saskatchewan River; magnetite prevailed in the concentrates from the Athabasca River; pyrite was found to be quite common in the heavy suites from the Peace River and its tributaries. Scheelite (Plate 34.2) and zircon seem to be common in all the river bars sampled. Platinum (Plate 34.1) was noticed only in the heavy fractions from the North Saskatchewan River.

Only a few grains (5) measured about 2-2.5 mm in size, the remaining 648 were in the range 0.5-0.010 mm. It should be mentioned here that mesh+60 and mesh+120 were more represented than other fractions not necessarily because they are the most typical size classes present in the placers, but for a series of other reasons which are discussed in more detail in other parts of this thesis:

1. Inefficiency of mechanical processes in recovering fine particles;
2. It is easier to identify and collect the coarser fractions.
3. Sluicing and panning was done during a period of exceptional runoff (except for samples 26, 27 and 28), therefore, the very minute thin flakes of gold were easily removed from the stream bed, at the time of sampling.
4. A set of grains of Mesh-230 (here also named MCP) was lost during inadequate mechanical polishing.

The histograms in Figures 31 and 32 show the size distribution of the analyzed gold grains from the two main rivers (North Saskatchewan and Athabasca, respectively). It will be noted that the grains in the size range 0.063-0.125 mm, or smaller, were more frequent in the concentrates collected from the Athabasca River, whereas in the North Saskatchewan River the size range 0.125-0.500 mm seems to encompass 90% of the gold analyzed and at least 80% of the grains counted in the heavy concentrates (Tables 2 and 4). The sample from the Redwater River almost invariably contained particles measuring 0.063 to 0.125 mm in breadth. The gold flakes from the Vermilion River were all collected in mesh+120 (0.125-0.250 mm) but the absence of the other fractions is the result of inadequate recovering processes and choice of sampling period. It may also be due to the presence of particles actually transported by the North Saskatchewan River, since the locality of sampling is exactly at the mouth of the tributary stream.

Five different phases could easily be distinguished by observation of colour and luster of the placer gold[3]:

1. A gold-rich alloy, represented by grains with very bright luster, reddish or pinkish yellow in colour (Plate 2.1 and Plate 3.1, 3.2);
2. A silver-rich alloy, with grains usually greenish yellow in colour and variable luster depending on the irregularities of the surface layer;
3. An alloy of intermediate colour, light yellow to orange (Plate 2.2);
4. Silver coloured particles (Plate 4.2): many of the gold grains, particularly from localities 26, 27, 28 (Emily Murphy Park, Edmonton) and, less frequently, from localities 25 (Devon) and 24 (Area below High Level Bridge, Edmonton), had a silvery coating of amalgam, apparently discharged into the river during milling operations, which took place exactly in this stretch of the river.
5. Grains with dull luster and colour ranging from brownish yellow to greenish yellow.

This wide variety is due to their different morphology and composition which reflect their different history and the composition of the original lodes.

A hundred gold particles were spread on SEM holders for three-dimensional examination. Three morphological types of gold could thus be identified:

1. Detrital gold;
2. Recrystalized gold;
3. "New gold" and/or gold probably associated with carbonaceous material.

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[3] Some grains had quite often red-stained patches or dark discontinuous coatings.

1. The detrital gold is not a principal component of the placer gold: it only accounts for about 1 to 5% of the total number of gold particles collected. The presence of these grain types is quite surprising since their morpholgy indicates that deposition occurred after transportation by rivers for a maximum distance of 50–80 km from the primary source. This points in favour of a different mode of transport (e.g., glaciers. Also the gold could have been liberated from drift material or from pebbles previously carried downstream (by streams).

   Detrital gold is irregular in shape, less flattened than other morphological types, with rounded protuberances (Plate 30.1); a few wire-like grains were also noticed (Plate 4.1). Crystals or crystal faces (Plate 30.2 to 30.5) are still visible on the surface, often in cavities and partially covered by the folded portions of the metal or partially distorted by scratches. Skeletons of octahedra commonly appear as triangular crystals (Plate 30.6): scratches are present and crosscut all these structures. Petrovskaya (1973) maintains that the dendritic, skeletal and distorted shapes of the polyhedra are typical of segregations of native gold from shallow gold-ore deposits. Dendrites preferentially grow in an enviroment of saturated and viscous solutions with participation from colloidal phases.

2. The second type of gold, a type derived from recrystallization and leaching of detrital gold, accounts for at least 90% of the gold grains studied. Recrystallized gold is usually flaky, scaly, and sometimes drop-like. Plate 2 shows two such grains from the North Saskatchewan River, and Plate 3, the largest from the Athabasca River. Scratches, scales, bent and hammered edges (Plate 32.5) can be observed on the surface of the grains. The micromorphology is jagged (Plate 19) and porous in particular when associated with gold of category 3 (Plate 31). These gold particles are sometimes very thin, less than 20 micrometers in thickness: the edges of these thin sheets have been bent into what Ramdohr (1965) defined as "sandwich structures" (Plate 32.1 and 32.3; Plate 33.3; Plate 19). Grains of other minerals are trapped in between, for example the quartz crystals

enclosed in the core of the grain shown in Plate 33.5, or the impurities seen in Plate 32.1 Attached quartz grains are quite frequent, usually being very small but sometimes visible at low magnifications (Plate 3.2: the vitreous string to the right side is essentially quartz). Plate 32.6 and Plate 19 show a quartz crystal embedded in the gold grain and a scar left by another impurity. Parallel (Plate 32.5) and randomly oriented scratches are sometimes present, although they are generally lacking.

The surface of the grains shows hammered laminae and is quite often pitted with small holes.[3] Grooves produced by other minerals (mainly quartz) are not uncommon (Plate 19), and quartz grains are often hidden in cavities and obscured by subsequant folding and stretching of gold laminae (Plate 19). On a few grains extensive parallel scratching was a prominent feature (Plate 32.5).

A variety of flaky grains similar to that described by Yablokova (1972) were noticed. These are represented by round/ellipsoid gold particles with peripheral ridge-shaped bulges, the so-called "toroid-like" shape (Plate 33.4 and 33.5, Plate 16, Plate 18). The toroid and drop-like varieties of gold show internal cavities filled with hook-like growths of gold (Plate 8.1, Plate 24.1 and 24.2). Petrovskaya (1969) and Yablokova (1972) suggested that grains of this kind derived by deposition of gold crysts on small nodules of organic matter and iron hydroxide in sedimentary rocks. The toroidal form has also been considered as a typomorphic feature indicative of relationship to Precambrian sedimentary rocks.

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[3] Sand grains appear to protect the gold from abrasion. The presence of even small amounts of sand greatly lessens the abraisive effects of pebbles and cobbles. Gold shows a very slow rate of physical breakdown when compared to most of the common rock-forming minerals. Gold is very malleable, and the physical changes produced by abrasion are mainly changes in shape. There seem to be high rates of weight loss in the early stages due to the rapid removal of the oxides which originally coated the gold released from the mother lode. Once the coating is removed the rate of abrasion decreases and becomes approximately constant. Most of the abrasion and physical changes produced in the gold are due to the cobbles, while sand seems to be responsible for only minor changes. Andersen (1926) stated that "sand submerged in water wears down more rapidly than dry sand transported over the same distance." Velocity appears to be more important as a factor in abrasion than the distance travelled. "A fivefold increase in velocity produced a tenfold increase in abrasion rates of gold"(Yeend, 1975). Yeend concluded that the presence of large cobbles and boulders with small amounts of fine-grained material in a high-velocity fluvial enviroment is the most effective situation for the abrasion of native gold.

3. "New gold and/or gold associated with carbonaceous material is dominated by a network of fibrelike filaments about 1 micrometer in thickness (Plate 15). It is usually associated with detrital gold particles originally trapped between the filaments of algal mats or lichenlike plants (Plates 20 and 21). The surface of detrital gold often shows small and/or wide patches of spongy appearance (Plates 15 , 31.3 and 31.4) which are actually attached fibrelike filaments. There are therefore many similarities with the gold from the Upper Witwatersrand and Ventersdorp Systems of the Klerksdorp Gold Field in South Africa (Utter, 1979)

B. MINERALOGY AND COMPOSITION

Petrographic studies

All the grains analyzed had a gold rich rim; for many of them it was not possible to determine its composition because the rim was too thin and discontinuous in character. Moreover, the optical system of the electron microprobe is not good enough to resolve the inhomogeneities of certain grains, where the difference in Ag content between core and rim is less than 5 wt%. Therefore, even if the beam was impinging upon the outermost part of the gold grain (where a rim was previously recognized under a reflected-light microscope) the points analyzed may have been areas of rim discontinuity. Petrographic study revealed the presence of the rim in almost 95% of the grains. The remaining 5% is represented by grains showing, in polished section, a typical lacy texture (Plate 11.1 and detail of another grain in Plate 11.2) which is the equivalent, in two dimentions, of the filamentous texture observed on certain gold grains ("new gold" and/or "gold associated with carbonaceous material"). This kind of texture is identical to that observed in partially amalgamated gold (Feather and Koen, 1973), where there is usually a porous zone, pale in appearance, representing the amalgamated portion of the gold; the colour becomes golden yellow towards the solid, not amalgamated areas of the gold.

Gold grains of this type are also present in the North Saskatchewan River, in particular in Edmonton City and the Town of Devon. The interesting fact about this texture is that it occurs also in grains where mercury is not present at all, at least in detectable amounts; moreover, the porous part of the grain is sometimes richer in gold than the central part of the gold particle : an example is shown in Plate 11.1 (grain #6-19M60) and 11.2. In other cases, such as grain 12-24M120 (Plate 12.2), the reverse was noticed. Accurate analysis of the rim could not be performed on the latter grain due to the vuggy texture of the gold (the total number of counts was too low and the Fortran IV Program rejected the data); qualitative analysis, however, revealed a higher concentration of silver in the outer portion of the grain: a silver peak can be observed in Plate 26.1 which refers to the above mentioned grain. Similar spectra were observed on gold grains ranging in composition between 56 wt.%Au and 70 wt.%Au. A possible explanation for this is that the rims acquired additional silver in amalgamation.

The morphological similarities of these low-fineness rims (probably due to natural amalgamation) with high-fineness rims having porous-lacy texture points in favor of a chemical origin for the latter kind of gold rim: it was probably deposited from solutions containing colloids of gold.

The high-grade film is sometimes present at the apparent core due to folding and consequent entrapping of originally outer portions : almost invariably a new rim was subsequently produced on the surface of the deformed gold grain.

Pliny the Elder (79 A.D.), in his book on gold, mentioned that an increase in fineness is observed with increasing distance from the primary deposit. Many centuries later, McConnel (1907) observed that the nuggets of the Klondike district show a superficial enrichment in gold in comparison to the composition of the nucleus. Electron probe analysis performed by Boyle (1979) on some of these nuggets and others from different placers, revealed a rim of greater fineness which is usually only a few micrometers in size (maximum 30 micrometers or 0.030 mm).

The same kind of rim was found by Johnston and Uglow (1926) on the gold of Barkerville (Cariboo) in British Columbia.

Fisher (1935) noticed the same effect on gold of Morobe (New Guinea) and maintains that silver is leached away whereas gold is not or, if removed, it is immediately redeposited. The surface refining action would be accentuated as the size of the gold grains decreases.

Boyle (1979) maintains that the rim effect represents the precipitation of gold (and some silver) on gold nuclei.

Desborough (1970), Desborough *et al.* (1970), Desborough *et al.* (1971), observed the presence of a microscopically visible low-silver rim on hundreds of gold grains from placer occurrences in the Western United States. The investigators stated that the rim formation is probably not due to deposition of pure gold films on the outer parts of the grains but is instead the result of selective depletion of silver by aqueous solutions with moderate to high oxidation potential.

A peripheral zone of high fineness (about 5 to 10 micrometers wide) near the rim of native gold collected from the Riam Kanan River in Southeast Borneo was reported by Stumpfl and Clark (1965).

Schmid (1972) studied alluvial deposits of the Eastern Napf-Area (Canton Lucerne, Switzerland) and determined the presence of zoning in the small gold flakes analyzed: the low silver content of the rim was considered to have been produced by silver depletion during downstream transport.

In the Russian literature, references on the subject are numerous; to cite a few: Petrovskaya and Fastalovich (1952; 1955), Perelyayev (1953), Nicolayeva (1958; 1968), Saprikin and Yablokova (1970), Sinyugina *et al.* (1967), Yablokova and Kyzhov (1972).

From the observations reported in these articles it is possible to conclude that the internal structure of placer gold can be altered in placer conditions under the influence of mechanical and electrochemical factors. The abrasion of gold by clastic material carried by the stream, the water flow on the surface of the metal and, in particular, plastic deformations, result in recrystallization and development of a high-fineness superficial rim. The presence of this rim would be macroscopically exhibited by a more "shagreen" character of the surface of gold.

Recrystallization of native gold in natural conditions, was commonly considered impossible, on the basis of metallographic principles, according to which recrystallization of metals happens only at a specific degree of deformation in conditions of temperature close to the melting point of the metal, clearly not possible at the surface of the earth. Therefore, it has been overlooked that at low temperature and with a lower degree of deformation the recrystallization of a metal occurs ,so slowly that a very long time is necessary. This phenomenon cannot, for this reason, be observed in the material used in construction.

The deformation of gold seems to occur at a very low speed in natural conditions, at low temperature and during an extremely long time. Plastic deformations are shown by the appearance of "surfaces of flow".

High-degree deformation is explained by transportation of gold in conditions of fast stream flow, in presence of relatively coarse clastic material.

The original, primary structure and composition of the gold is rarely completely obliterated (this was noted in very fine-grained, well rounded gold, such as the example shown in Plate 6.2) essentially because its high malleability allows the metal to react to deformation factors by producing surfaces of flow, thus preserving the core of the grain and, with it, all the information concerning the type of gold-bearing ore from which the placer gold was derived.

Recrystallization seems to be typical of old, buried, placers. When gold remains in the placer without being subjected to transport, the conditions are also favourable for the formation of redeposited gold ("new gold") from circulating groundwater. There are, in these conditions, more chances for the preservation of the spongy crust of new gold; during transportation it may be easily destroyed.

In the old buried placers the pressure of the overlying sediments and lithification may determine the compaction of the spongy structure into a less vuggy, more solid rim (Plate 12.1) and the gradual expulsion of entrapped water stops any further supply of gold. But it is also possible that a compacted rim may result from mechanical interactions of the gold grain covered with patches of spongy, "new" gold with other clastic material. If the stream current is not too strong and gold travels and collides mainly with very fine material, conditions may exist for the preservation of the spongy crust and even for its compaction. It is possible to speculate on the occurrence of combinations of the above mentioned factors and events. It is not difficult to understand why different stages of recrystallization and kinds of rim are frequently noticed.

Electron microprobe study

The results of the electron microprobe studies of the placer gold are reported in tables 9 to 80; they were obtained using a Fortran IV Program called "FENICO" (Smith and Launspach, in preparation): this name derives from the fact that the program was originally devised to calculate data from analyses of metal grains in meteorites in which Fe, Ni and Co are the main elements.

Au, Ag and Cu were calculated simultaneously so that the total wt.% of the three elements could be determined for each point analyzed. The program assumes the total wt.% of the three elements to be 90% or more; if less than 90%, data are rejected.

A series of standards, of composition similar to the specimens to be analyzed, were available, so that the various correction factors could be completely ignored.

On the basis of the counts on the standards, the program builds up calibration curves for Au and Ag and a Cu background curve which allows correction for Cu K_α background.

Qualitative analysis of many grains revealed that they were essentially binary alloys (Au,Ag), or ternary alloys (Au,Ag,Cu) where Cu concentration was low enough not to warrant any ZAF correction.

Only background correction, as mentioned, was applied for Cu, so that its concentration results from the following equation:

Cu = [(Cu sp.peak−Cu sp.bg)/(Cu std.peak−Cu std.bg)] × Cu std./1, where Cu std. is the concentration of Cu in the standard.

In some grains, other elements were also detected in very small amounts, such as Fe and Pd; Si, Al, Ca, K, Zn, Fe, Hg and Ti were present in mineral inclusions or as impurities on the surface.

Homogeneous standards of the following composition were used (all in wt.%) : Au_{100}, Ag_{100}, Cu_{100}, $Au_{60}Ag_{39.9}$, $Au_{40}Ag_{59.9}$, $Au_{22.5}Ag_{77.5}$. Operating conditions were:

1. probe current 10^{-8} Amperes,
2. aperture current 10^{-7} Amperes,

3. operating voltage: 15.0 kV,
4. counting time on standards: 200 seconds,
5. counting time on samples: 20 seconds.

The intensities of the following spectral lines of the standards and samples were measured with the indicated analyzing crystals:

Au M_{α} - PET
Ag L_{α} - EDS ROI
Cu K_{α} - LiF

In general, between 4 and 10 analyses were performed on the nucleus of each grain and at least 4 on the rim. Moreover, a sequential analysis of points along a straight line, across many of the grains, was carried out: the results are shown in Figures 11 to 15.

The contact between nucleus and rim was always found to be sharp with no gradational transition between one and the other.

Description of the rims.

-Athabasca River.

Four different categories were recognized:

1. Very discontinuous rims, ranging in size between 0.001 and 0.01 mm. The composition of the grains having this kind of rim is 20-24 or 35-40 wt.% Ag at the core, and 2.5-7.0 or 8-9 wt.% Ag at the rim, respectively . A typical example is present on grain #18-2MCP (Plate 5.1).
2. Continuous, very thin, high-grade films, 0.002 to 0.01 mm in thickness; there are also areas where it reaches 0.02 mm but they represent deformation zones, overlapping, as a new very high-grade film, the previous thin one. This is visible, for example, in grain #2-2MCP (Plate 5.2). The step-scan profile across this grain (Fig. 15), also illustrate this feature.

   The composition of the grains having this kind of high-grade film is about the same as group 1. Groups 1 and 2 seem, therefore, to be represented by grains of electrum or very close to the composition of electrum.
3. Continuous rims, maximum up to 0.02 mm in thickness. This class is characterized by grains having a nucleus with less than 20 wt.% Ag (usually around 13 wt.% Ag) and a rim containing 4-7 wt.% Ag.

   This zoning is not evident in grain #1-2MCP (Plate 6.1) because the difference in composition is usually around 5-7 wt.% Ag, but its existence is proved by a step-scan profile across this grain (Fig. 15).
4. Gold highly recrystallized, with a rim thickness of at least 0.03 mm and representing about 90-95 % of the volume of the grain. An example is shown in Plate 6.2 and Fig. 15 (grain # 2-2M230).

   The content of silver in the nucleus is about 10-14 wt.% and 3-5 wt.% in the rim.

-North Saskatchewan River.

Six groups have been identified.

1. Very discontinuous, dendritic, porous rims, up to 0.020 mm in thickness, usually present on grains having a high Ag content in the nucleus. A typical example is shown in Plate 7.1, Plate 7.2 and step scan of Fig. 3. In this category the nucleus has a compositional range of 44 to 20 wt% Ag and the high-grade film of 3-5 wt% Ag.

   A very strange kind of high-grade areas is present in grains of the kind shown in Plate 8.1, in the secondary electron pictures of Plate 24 and the step-scan of Fig. 12 (all referring to grain # 39-28M120): the average Ag content of the nucleus is 22.07 % whereas it is 17.66 % for the rim; at the same time, some areas of the grain, not necessarily of the edge, have a very low concentration of Ag, such as the hook-like growth of gold filling cavities.

2. Discontinuous rims, usually present preferentially on two thirds of the grain surface and along one of the two largest sides. This is well visible in Plate 8.2 (grain # 12-24M60), in the backscattered and X-ray pictures of Plate 27 (grain # 11-25M60): they are always well developed where plastic deformations occurred. Except for the latter areas, the rim ranges in thickness between 0 and 0.025 mm.

   These grains usually have a silver content of 19-25 % and a high-grade film Ag content of about 3-6 % (grain # 11-25M60, Plate 27; grain # 35-25M60, Plate 29).

3. Very thin, continuous high-grade film particularly evident, again, where plastic deformations induced recrystallization. Examples can be observed in Plate 9.1 (grain # 57-25M60) and in Plate 9.2 (grain # 56-25M60). The rim is not clearly visible in these photographs and also in Plate 10.1 (grain # 19A/B-24M60) because the inhomogeneities are not very pronounced: in this case the nucleus has a silver content in the range 9-11 wt% and the

rim, usually, 4-9 wt%.

Different, consecutive generations of rims are also a common feature; for example, the grain shown in Plate 9.2 (grain # 56-25M60) is folded for more than one third of its length and the rim enclosed within the fold has a silver content of 7-8 %. The same is valid for grain 19A/B-24M60 (Plate 10.1). This grain is strongly folded and the two parts (A and B) have essentially the same composition except for the rim: the high-grade film around B has a lower content of Ag (3.96 wt%) than the one on the upper surface of A (9.92 wt%), at the contact between A and B.

Grain # 57-25M60 (Plate 9.1), has a high-grade film in particular around two apophyses at the central area of the grain itself: it is here that gold reaches its maximum concentration (about 96 wt%).

4. Continuous high-grade films of about 0.025 mm in thickness, usually lining grains whose core have a composition of 80-90 wt% Au and 10-20 wt% Ag (mainly 11-13 %).

It is also possible to note from Plate 10.2 (grain # 35-26M120) that a dendritic, porous area is covering the surface of the grain but is also present on what used to be the original surface of the gold particle, preceding its folding.

Where the gold filaments were compacted enough, it was possible to determine their compositions: they proved to be almost pure gold (98 wt% Au), or gold of lower fineness (about 80 wt% Au). These heterogeneities of the filamentous, porous rim, exhibit a different colour in the picture.

5. Continuous rims reaching a thickness of 0.100 mm or more (Plate 11.1, Plate 11.2 and Plate12.1 shows polished sections of grains #6-19M60, 1-26M35 and 19-28M120, respectively).

The presence of these thick rims also on grains as big as those separated in fraction M+35 (up to a few mm), is quite surprising. Proportionally thick rims were also noticed on grains from M+60, M+120 and M+230, which means that the process of refining of this gold was a general phenomenon involving grains of different size.

An overall assay of these grains would indicate a medium to high fineness, but the nucleus has actually a very high Ag content (at least 20 wt.%); the rim contains about 3-4 wt.% Ag.

The shagreen texture of the grains can be better observed in Plate 15, where the filamentous, fibrelike, spongy appearance strongly suggests a completely different origin of this gold. This network is composed of branches of filaments averaging about 1 micrometer in thickness. Grain #12-24M120 (Plate 12.2) is a representative example of a category of grains which could not be properly analyzed. This problem arose because in microprobe analysis, the primarily excited volume extends some depth below the surface (at least a few micrometers) so that the material actually analyzed is the average of what lies below the surface and within the excited volume. In the case described, most part of the volume is represented by epoxy resin or voids (vugs), since the filaments of gold are as mentioned, 1 micrometer in diameter (or up to a few micrometers). Therefore, the counts obtained during electron probe analysis were very low and the FENICO Program rejected any data when the sum of the three elements simultaneously analyzed (Au,Ag,Cu) was less than 90 %.

Also interesting are Plates 20 and 21 where "new gold" tying together grains of different composition is clearly visible(Plate 20.1 and Plate 20.2 are backscattered electron pictures of grain # 61A/B/C/D/E-26M60; Plate 21.1 and Plate 21.2 are backscattered electron pictures of grain # 2A/B-28M120). A three-dimentional example of this effect is shown in Plate 17.

6. Another group is represented by grains naturally amalgamated by mercury: grains up to 5 mm in size were found: they were composed of many indivudual grains held together (as shown in Plate 4.2) by amalgam. Some mercury was detected (spectra of Plates 25.3, 26.2 and 26.3) but the amount was not calculated since quantitative analysis was not performed.

The pale rim of amalgam is shown in Plate 14 (Grain # 22-28M120) where it lies on a high-grade film which is not visible, again due to the small difference in Ag content of nucleus and rim.

Mercury has sometimes invaded the lacy, spongy texture of grains lined by "new gold" and/or create a similar texture (Plate 13.1; grain # 15A/B/C/D-20M60 has a small particle of electrum held together with particles of higher fineness) which appears in Plates 22 and 23 as an outer topographic feature.

-Redwater river.

This river is mainly characterized by the presence of certain typomorphic variety of gold: the toroidal grains. Plate 24 (secondary electron pictures), Plate 8.1 and Plate 28 (backscattered and X-ray pictures) are typical examples of these grains: they have big cavities sometimes filled by inclusions.

They also have a high-grade rim, usually very thin, and apophyses (formed along surfaces of flow) having a very high Au content (95-98 wt.%, or more).

The composition of the nucleus is mainly of two types: one ranges 70-78 wt.% Au, the other 81-90 wt.% Au.

-Vermilion River

The grains from this river do not seem to differ from those found in the North Saskatchewan River (groups 1 to 3) as far as the rim is concerned, and they probably have a similar history.

Fineness of recovered gold

The fineness of the analyzed gold has been expressed in the form 1000 x Au/(Au + Ag), so that the base metal content is ignored, as recommended by Fisher (1945).

The fineness of gold from placer deposits usually varies from about 500 (electrum) to 999 (pure metal) but for most placers it shows a fineness of more than 850. The fineness of vein gold is usually in the range 500-900 , and always lower than the fineness of the placer gold which is derived from it.

In California (Lindgren, 1933), vein gold fineness averages 850 and is the souce of placer gold averaging 930-950 in fineness. In Yukon Territory and Northwest Territories (Yellowknife) the primary gold was found to be in the range 900-950 (Boyle, 1979) whereas the supergene gold was about 990 fine.

The gold from oxidized zones of ore deposits is usually higher in grade and is further refined in placers due mainly, according to the majority of the investigators, to the leaching of silver. The formation of the enriched rim starts in near-surface deposits (mainly Tertiary), in oxidation zones or in eluvial deposits, but it seems to be a rare phenomenon in deep-seated deposits.

The distance travelled in placer conditions, the length of time the gold has been exposed to the physical and chemical conditions of a particular fluvial environment and climate, the size of the gold grains, their ratio surface/thickness (or better, their Corey Factor) are important factors in the refining process.

Fisher (1945) found the fineness of gold to increase from 0.3 to 7.5 units with each kilometer from the source, but in other placers the fineness was noticed to fluctuate going downstream or even decreased (Bilibin, 1938).

The fineness of gold in placer deposits clearly depends, besides the factors above mentioned, also on:

1. The erosional history of the area and, in particular, of the various parts of the orebody(ies);
2. Sources of supply eroded by the river;
3. Stream conditions;

4. Size of the gold grains. As Koshman and Yugay (1972) suggested, it may happen that large grains of high fineness, although eroded first, tend to concentrate near the deposit.

A typical exception to the general rule that gold grains in placers show an increase in fineness with increasing distance of transport from the primary source, is the gold from the fossil placers of the Witwatersrand, which appears to have retained its primary fineness (Hallbauer and Utter, 1977), probably because the environment was strongly reducing and there was not enough free oxygen to leach the silver out of the gold grains.

The silver and gold contents of ore-samples were obtained, in the past, mainly by fire assay: those values yield, therefore, the fineness of the total metals analyzed which is different from the fineness of the individual gold particles; besides that, it overlooks the fact that there may be inhomogeneities in each grain. This is the reason why the electron microprobe is very useful in determining the "in situ" composition and the inhomogeneities (if any) of single grains.

Since it is believed that the nucleus of placer gold still preserve (to different extents) the original composition of the lodes from which the gold derived (primary inclusions are sometimes visible, above all pyrite and quartz), the fineness of both the nucleus and the rim was determined and treated separately, and subsequently compared. Figures 16 to 19 show the fineness in the nucleus of 440 gold grains from the North Saskatchewan River, of 86 grains from the Athabasca River, of 12 grains from the Redwater River and of 13 grains from the Vermilian River. Moreover, the fineness of 144 grains from the same locality (26) along the Saskatchewan River was considered separately.

The first observation that can be made is that *there is no increase in the average fineness of the core of the gold grains on going downstream, and differences are shown by the various size classes. In particular, the average Ag content increases for decreasing size of the grains.* There is also a pronounced bimodal distribution of the fineness values in the North Saskatchewan River for mesh +230. At least two-thirds of the gold grains analysed from the North Saskatchewan River have a fineness in the range 850-960. The rest are scattered towards lower values, close to 550 in some grains.

In the Athabasca River there seems to be a more pronounced concentration of values around three main ranges: 850-950, 760-790, and 625-670. The values for the Redwater River and the Vermilion River are scattered between about 700 and 950 fineness, with a slight bimodal distribution for the Vermilion River.

The overall picture of the data on the fineness of gold particles in alluvial deposits in Alberta suggests that the gold was derived from *multiple sources.* The variation in composition could be due both to contributions from different areas or from a single source containing gold with different compositions, representing different stages of emplacement. Primary intragrain inhomogeneities are rare or negligible in the overwhelming majority of the grains, so that the first hypothesis is more reasonable.

Another way of testing the validity of speculations on the origin(s) of the placer gold is to plot the compositional data for the rim and nucleus of each gold grain. This is represented in figures 20 to 23 by the symbols (a star for the rim, and a square for the nucleus) connected by a line: the top end represents the maximum content of silver in the core of each grain, while the bottom of the line represents minimum silver content observed in the same grain. Sometimes the lines are very small, and this means that the compositions of the nucleus and rim are not very different. Often, however, the polishing was stopped before exposing a wide portion of the nucleus so that the apparent difference is not pronounced. It will be noticed that only 353 grains out of 442 have been plotted in figure 20. Those grains that are partially amalgamated have been excluded, together with those for which the data on the rim was inadequate to distinguish it properly from the rest of the grains. The same criterion was used for grains from the Athabasca River.

North Saskatchewan River.

Five-sixths of the gold grains appear to have been subjected to the same refining process. This produced a rim with less than 5 wt% Ag, although the original compositions were quite different. There was a supply of material of very low fineness (20–45% Ag) together with gold which had a range of 8–20% Ag at the source. The remainder of the grains had a different history. These may have been contributed by a relatively more recent fossil placer, or they may represent the influence of other factors. These may include the migration of stream beds due to glaciation and therefore collection of gold from other drainage systems of the same region, or from drift carried by glaciers from other formations present in the shield.

The greatest range in silver content in a single grain is 4.29–46.13 wt.%. The average silver content for each size class (Table 3) increases with decreasing size of grain from 13.1 wt% (M+35) to 18.6 wt% (M+230). The same trend is shown by the standard deviation (6.3–9.3 wt% Ag). It is then possible to infer that the smallest fractions in particular (M+120 or smaller) are the result of multiple sources.

Athabasca River (Fig. 21).

Almost all the grains show the same degree of refining, producing a silver content in the rim of under 5 wt% Ag. Values are obtained for the silver content of the gold at source(s) of 8–15 wt%, 20–25 wt%, and 33–40 wt%. The greatest range in a single grain is 7.53–37.81 wt%. Again the average silver content increases with decreasing size, from 10.8 wt% (M+120) to 17.91 wt% (M–230 or MCP). Similarly the standard deviation (SD) increases from 5.0 to 10.1 (Table 5).

Redwater River.

Two groups of grains are present here. One shows a high degree of silver depletion from the rim (less than 5 wt% Ag). The composition of gold at the source was in the range 10–18 wt% Ag.

The other group is characterized by high silver content in the rim (about 15%) and seems to be represented by grains with an original composition of 30 wt% Ag and 70 wt% Au. The average silver content (Table 7) was 14.1 wt% with a standard deviation of 6.7 wt%. It was not always possible to determine the composition of the rim, however the value obtained for the nucleus was plotted in figure 22.

Vermilion River (Fig. 23 and Table 8)

A single group, characterized by the rim composition is typical of this river. Whereas two source groups are quite evident from the diagram with ranges in silver content of 7-13 wt% and about 25 wt%. The average was 11.4 wt% Ag with a standard deviation of 7.7 (Table 9).

Copper was present in the majority of the gold grains analysed, although values were generally less than 0.1 wt%. The maximum values of around 1.0 wt% were obtained from grains of M+120 from the North Saskatchewan River (Fig 24). The sample from the Athabasca river had a higher number of grains containing copper. The highest values (0.2-0.6 wt%) are again characteristic of M+120 (Fig.25).

A group of grains with no copper and another with over 0.1 wt% Cu distinguish the sample from Redwater River. Almost all the gold from the Vermilion River contains less than 0.1 wt% copper.

Desborough (1970) observed that cupriferous gold probably occurs mainly in deposits lacking sulfur as sulfides, such as gold associated with platinum deposits, where the metals are present principally as alloys. Desborough found that in placer gold, copper is depleted in the outer margin in the same way, and by the same process (leaching) as the silver. Ramdohr (1965) obtained the same results studying placer gold from the Rhine River.

In the present study, copper was found to be irregularly distributed in the grains, but preferentially concentrated in the nucleus. Gold from the Athabasca River proved to be the only exception , where the reverse occurs frequently (Tables 10(1M120), 16 (2M230), 19 (2MCP), 23 (3M230)). M+230 from the North Saskatchewan River tends to have the same Cu content and Au/Ag ratio as groups of similar size grains from the Athabasca River.

Gold/silver ratios.

The gold/silver ratio is a good geochemical indicator of;

1. Conditions existing at the time of deposition, namely: T, pH of the solution, depth.
2. Metallogenic epochs.
3. Mobility of the two elements.
4. Mining districts provenance.

Figures 24 to 27 show plots of the gold-silver ratio against the wt% of copper for each area studied. The lowest gold-silver ratios are usually around 1.2 for grains from the two main rivers, and about 2-3 for the other two rivers. Most of the ratios are in the range 2-16 with some higher values from the North Saskatchewan and Redwater Rivers (up to 22).

Eales (1960), in his thesis on gold fineness in hydrothermal ores, stressed the importance of taking into account not only temperatures of deposition, but also chemical differences of the ore-fluids, and differences in the paragenetic relationships of gold. Eales maintains that gold may crystallize in company with a number of ore minerals, therefore it is not confined to any one stage in the paragenesis of ore minerals. Gold crystallizing early in the paragenetic sequence tends to contain more silver than that which crystallizes in the final stages of ore deposition. It was found that in those deposits where the gold fineness is the most variable, the crystallization of gold extended from early in the paragenesis to late. Whereas the gold fineness is more constant in those deposits in which the period of crystallization of gold is very short relative to other ore minerals. Gold is often precipitated until the last stages of mineralization. Silver, however, shows an increasing tendency to remain in solution. "Late gold" should then increase in purity, while gold alloyed with a relatively high proportion of silver would be earlier. The increase in average fineness with increasing depth would be due to differences in the age of the gold relative to other ore minerals at different levels.

Distance travelled by the gold grains

Morphological and chemical variations of the gold particles with increasing distance from the original source commonly occur in placer deposits. Since the two parameters are associated, the distance of transportation can be estimated. By comparing the morphology of the grains studied with particles from other alluvial deposits (Ramdohr, 1965; Hallbauer and Utter, 1977) it is possible to estimate the distance of transport of the placer gold. As cited before, Fisher maintained that the fineness of gold increases from 0.3 to 7.5 units with each kilometer from the source. If we assume that the fineness of the nucleus is the original fineness at the source, it is possible to compute the approximate bulk fineness of the grain. From the difference between this value and the fineness of the nucleus it is thus easy to calculate the total increase in units of fineness and therefore the maximum and minimum possible distance travelled. It was found that the Albertan gold had travelled different distances along stream beds as a function of the different degree of recrystallization thickness of the rim and the ratio of Volume of rim/Volume of rest of grain. The gold had clearly travelled a minimum distance of 30km, and a maximum of 300km. It is believed that the exact reconstruction of the movements of the grains would prove very difficult, as glaciation played an important part in complicating the simple alluvial pattern described above.

Gold grains typical of a certain river have been mixed with those from others during the migration of drainage channels during the Pleistocene Period. The presence, at different localities along the same river, of grains having same size, same quality of rim and silver gradient, can be explained with the reworking action of the Pleistocene glaciers. Further development of the high grade rim was stopped or strongly diminished by the glacial ice and low ambient temperatures.

Gold from the Cretaceous Formations, was dispersed in pre-Quaternary alluvium; part of the placer gold was eroded away from the bedrock during glaciation and added to the sediments as outwash material. The erosion of drift then released and reconcentrated some of the native gold. The placer gold from

Alberta is therefore considered to be *polycyclic*.

Richer placers possibly occur also in the Foothills Area, but are still covered by overburden.

C. STATISTICAL TREATMENT OF THE RESULTS

Frequency diagrams

410 grains from the North Saskatchewan River have been considered when plotting the histograms of Figures 31 and 33. 32 grains were not included because each single particle was actually an aggregate composed of many smaller ones amalgamated by mercury (Plate 4.2); the grains from the Athabasca River were all included. The sample has been divided into different fractions on the basis of the mesh in which the grains have been collected (this is mainly representative of their breadths) but also on the basis of their equivalent diameter. This latter parameter has been considered more relevant than the former, and more emphasis has been given here to the results obtained using this.

The diagrams of both Figures 33 and 34 are positively skewed, although skewness is less pronounced for the sample from the Athabasca River: the distribution tends to be normal. The first diagram exhibits a distinct leptokurtosis (high degree of peakedness) whereas the other is more mesokurtic.

If we assume that kurtosis is related to maturity, a smaller kurtosis and a smaller degree of asymmetry (skewness) imply here a lower degree of maturity for the gold from the Athabasca River.

An attempt was made to relate the equivalent diameter to the Corey shape factor of the native gold. The long axis, the breadth and the thickness of each grain were calculated in order to determine both the equivalent diameter $[\sqrt[3]{(6/\pi)LBT}]$ and Corey shape factor $(T/\sqrt{LB})$, where L, B and T represents length, breadth and thickness, respectively.

The flatness ratio is usually expressed with Wentworth's formula $(A+B)/2C$ which is the arithmetic mean of the length and breadth divided by twice the thickness.

The Corey shape factor has been used here to describe the flattening of the gold grains; it is defined as being the ratio of thickness over the square root of length x breadth $(T/\sqrt{L+B})$. Small Corey factors are indicative of flattened grains, large factors mean that the particles are more spherical (Tourtelot and Riley, 1971).

The more the shape of the particles differs from spherical (or, in other words, the more they are flattened), the more easily they are transported by stream currents. Therefore, it is important, when trying to solve problems related to the origin of placers, to take account of the shape of the grains. The larger the particles, the greater the probability of collisions with sand grains: this should result in lower values of flattening (low Corey factors).

Tishcenko (1981), after studying the evolution of gold-flake flattening in alluvial placers, concluded that the flattening first increases regularly with the size of the gold flakes, and after reaching a maximum it also decreases regularly. According to Tishcenko, flattening of gold flakes in the range 0.5-3 mm (the so called medium-sized gold-flakes) is the most variable.

The gold flakes tend to lie on their flat sides and this surfaces are worked mainly by particles moving more rapidly.

It is commonly believed that gold tends to become smaller and more flattened with transport, in order to oppose less resistance to the currents: the flattening of the gold flakes would therefore increase as a consequence of the preferential removal of metal from the two opposing larger surfaces of the particles. This rule is not always valid for fine-grained gold (<0.1 mm) since the flattening tends to be, in many alluvial placers, equal to that in the coarsest fractions, and of very low amount.

Fine gold is transported at a different (higher) speed than coarser gold, and rolling is more common. It has been determined (Vistelius, 1960) that sphericity increases during prolonged rolling of a particle.

The gold from the North Saskatchewan River and Athabasca River has been subdivided into five size classes (Tables 2 and 4) and the equivalent diameters plotted against their Corey shape factors (Figures 35 to 45); moreover each size class can be easily recognized since it is represented by a different symbol.

-North Saskatchewan River.

The diagram in Fig. 36 (Mesh+35) shows an increase in Corey factor with increasing equivalent diameter, which means that the grains are less flattened with increasing size. The flatness values vary from about 0.048 to 0.155.

The same trend can be observed in Fig. 37 for Mesh+60, with values between 0.035 and 0.400.

The diagram in Fig. 38 (Mesh+120) again indicates an increase in Corey shape factor with increasing size, although it looks less pronounced, also because the vertical scale is different. Corey factors are mainly in the range 0.070-0.350 but they also reach maximum values around 0.800-0.900.

The plot in Fig. 39 (Mesh+230) shows an opposite trend, that is decreasing values (0.280 --->0.130) of Corey factors with increasing equivalent diameter.

In conclusion (Table 82), increasing Corey factors for grains of Mesh+120 or larger (which means increasing sphericity) were obtained; the opposite pattern is valid for M-120.

It is possible to note from Fig. 35 an overall trend towards decreasing Corey factors (0.350 --->0.040) for increasing equivalent diameters (80 --->300). By converse, with further increase of equivalent diameter (300 --->700) the Corey factor, in the average, increases (0.040 --->0.370).

Since the 410 gold grains represented in the diagram of Fig. 35 come from different localities along the North Saskatchewan River, it was decided to test the trend of these variables for grains of a single sampling site (Locality 26) in which the four different size classes were represented (Fig. 40). The distribution that results is slightly different but it follows a similar pattern.

If the shape factor is plotted against the $\log_{10}$ of the equivalent diameter (Fig. 41) this relationship is slightly more pronounced.

-Athabasca River

The data for this river are more complicated (Fig. 42, Fig. 43 and Table 83).

The Pearson's product-moment coefficient of linear correlation (normally referred to as "r", the correlation coefficient) was used to assess whether a linear relationship between the two variables (Corey factor and equivalent diameter) does exist.

The formula $r=CSCP/\sqrt{(CSSX\ .\ CSSY)}$ was applied, where:

CSSP (corrected sum of cross products) $=\sum xy - \sum x.\ \sum y/n$,

CSSX (corrected sum of squares of x) $=\sum x^2 - \sum x.\sum x/n$ and

CSSY (corrected sum of squares of y) $=\sum y^2 - \sum y.\sum y/n$.

This formula is the ratio of how much x and y vary together about their means to the total variation of x and y.

Values of r can vary between −1 and +1. When r=+1 perfect sympathy exists between x and y, therefore there is a perfect linear relationship between the two variables. When r=−1 perfect antipathy exists between x and y. If r=0, there is no linear relationship between the variables.

The values of r for Mesh+230 of the four localities (5, 3, 2 and 1) are −0.93, +0.578, +0.237 and −0.23, respectively, with an overall average of +0.06. This implies that there is no linear shape/size relationship for the grains studied; a high negative value for locality 5 and a high positive value for locality 3 are, however, noteworthy. They are indicative of two opposite trends for the same size class and drainage system (Plate 33.1, 33.2 and 33.3 shows two different morphologies of gold particles: a very flaky variety and a very round one, the first from locality 5, the second from locality 2).

The grains having the smallest size (Mesh −230, or MCP) are the most refractory to a linear relationship. A log scale for the equivalent diameter does not produce any remarkable change (Fig. 43).

The diagrams of Figures 42 and 43 indicate that for the same range of equivalent diameter there are two different groups of gold grains, both from Mesh−230 (MCP).

There is a wide scatter of values for M+230 whereas for M+120 they are concentrated into a single group.

If we compare the results obtained from all the sample studied, a few points can be stressed:

1. In the Athabasca River, the highest values of equiv. diam. from Mesh+230 coincides with the lowest values of Mesh+230 from the North Saskatchewan River. No comparison of Corey factors could be attempted since there are no available data for the latter river.
2. The values of shape factor for Mesh+230 of the two rivers have a common range but there is a spread towards both higher and lower values for the gold grains of the Athabasca River.
3. The data (Corey factors) for M+120 are, on the average, appreciably higher, in the Athabasca River.
4. Less flattening and sorting is a typical feature of the gold from this river, which is also suggested by the histograms of Figures 33 and 34.

-Redwater River (Fig. 44).

Values are quite similar to those from the main river, except for the equivalent diameter which tends to be proportionally smaller. These are the ranges:

Mesh+230; Corey S.F.: 0.16 --->0.30 (Max. around 0.52); Eq.diam.: 75 --->110.

-Vermilion River (Fig. 45).

The ranges of shape factors and equivalent diameter indicate high values; the equivalent diameters are similar to those from the North Saskatchewan River but the grains are less flattened. The data are as follows:

Mesh: +120 ; Corey S.F.: 0.11--->0.70; Equivalent diameter: 160--->300 (with max. around 460).

The number of grains studied does not allow a statistical treatment of the results.

Concluding remarks

The grains amalgamated with mercury have not been represented in the plots already described; the other gold particles are mainly flakey in shape, with folded edges; some are toroidal; many of the smallest particles are droplike, repeatedly folded, so that their shape factors become quite high. This is particularly true for mesh-230 (MCP) plus some grains of mesh+230 of the Athabasca River (0.50-0.90), and also for mesh+120 of the N. Saskatchewan River. Mesh+230 of the latter river also has high values (0.130-0.350), in the average higher than most of the grains of mesh+60 or even mesh+35.

The shape of some grains hindered or rendered impossible a good determination of the three main dimensions, such as the grain in Plate 4.1.

Wang and Poling (1981) determined the Corey factors for the Hill's Bar placer gold. Their results, too, indicate that the shape factor of the gravity recovered gold increased as the size of the gold became finer whereas the gold particles lost to the tailings indicated very low average Corey S.F. (0.14). The average factors of gold grains (<150 micrometer in size) isolated from many placer deposits in Alaska (Cook and Rao, 1979) vary from location to location, but

1. The average shape factors of gold from the tailings was always less than those from the heads and tended to increase as particle sise increased.
2. The shape factor of the gold from the "heads" increased as particle size decreased.

The difficulty in recovering fine platy gold (having shape factor less than 0.15) is a very serious problem which needs to be overcome if gold has to be recovered in Alberta.

D. CONCLUSIONS

During the early days of mining in the North Saskatchewan River, a considerable amount of money was spent in searching in the mountains and on the upper reaches of the river for the primary sources of the placer gold, but without favourable results. An origin from the glacial till transported across the plains from the Canadian Shield was thus postulated. This theory did not constitute a satisfactory explanation of the source of the gold mainly because increased showings would be expected as one approached the source of the glacial drift; on the contrary, gold concentrations are higher in the portions of the streams where the quantity of till is relatively small.

Also the possibility of a source from Cordilleran glacial deposits was considered, but the lack of a significant increase in gold content towards the west could not be explained.

Other authors (Tyrrel, Taylor, Rutherford) favored the possible origin of the placer gold from the coal-bearing rocks of the Edmonton Formation and/or Paskapoo Formation.

Since the presence of lodes in the Rocky Mountains could not be proved, the placer miners concentrated their attention on the exploration of the sand bars in areas where the Edmonton Formation outcrops. Officially, some 31,788 oz. (about 989) kilograms of gold werte recovered from the North Saskatchewan River from 1887 to 1981. Two peaks are noteworthy, one in 1896 (2661 ounces or 83 kilograms) and the other in 1980 (4276 ounces or 133 kilograms).

The results of a systematic prospecting conducted in Alberta by Halferdahl (1965) show that sand bars having gold concentrations high enough for economic recovery occur along the North Saskatchewan River, the McLeod River and perhaps the Red Deer River and the Milk River.

The main objectives of the present thesis were to study the distribution, the mineralogy and the morphology of placer gold in Alberta, and to locate its primary source(s).

Three morphological types of gold could be identified:

1. Detrital gold.

   It is irregular in shape, less flattened than the recrystallized gold; crystals or crystal faces are still visible on the surface or are hidden in folded portions of the grains. Scratches are present.

2. Recrystallized gold.

   Its main feature is the presence of a high-fineness rim due to plastic deformation, redeposition of colloidal gold and leaching of silver. It is usually scaly in shape but some gold particles, in particular in the smallest fractions (Mesh+230 or smaller), were sandwiched into more compact, sausage-shaped grains. Scratches are not a typical feature.

3. "New gold" and/or gold associated with carbonaceous material.

   It is composed of a network of fibrelike filaments about 1 micrometer in diameter, sometimes up to 5 micrometer. It usually helds together grains of other morphological types.

In placer conditions the structure of the placer gold was modified under the influence of mechanical and electrochemical factors, with consequent development of a high-fineness rim. Plastic deformation always plays a major role whereas leaching of silver is sometimes of secondary importance. Deposition of "new gold" is postulated to explain the spongy texture of certain gold rims. Petrographic and microprobe studies revealed the presence of a high-fineness rim on the majority of the gold grains. The contact between nucleus and rim is always sharp. On some grains the rim is continuous, on others it is discontinuous; its thickness is variable.

Naturally amalgamated gold was noticed in samples from the North Saskatchewan River.

Since it is believed that the nucleus of placer gold still preserves the composition of the primary source, the fineness of the nucleus of each individual grain was determined. It is possible to conclude that there is no increase in the average fineness of the core of the gold grains on going downstream. Differences are shown by the various size classes: the average Ag content increases for decreasing size of the grains.

Two-thirds of the gold grains from the North Saskatchewan River have a fineness in the range 850-960; the rest are scattered towards lower values, down to 550.

Three main ranges of fineness were noticed for the Athabasca River, namely: 850-950, 760-790 and 625-670.

Copper was also detected in almost all the grains analyzed. It is usually less than 0.1 wt% with maximum values around 1.0 wt%, and is preferentially concentrated at the nucleus of the grains .

The fineness of gold in gold deposits is likely to be an indicator of the saturation of the mineralizing solutions. Slow cooling is prevalent at greater depths, so that the mineralizing fluids deposit gold of high fineness (>900). In addition silver tends to remain in solution. Gold of low fineness is deposited near the surface under lower temperature conditions. Silver is not stable at these shallower levels, and is deposited in alloys with gold, giving a range in fineness of 500-750. Gold of intermediate fineness (750-900) will be deposited at medium depths.

The fineness of the gold analyzed from Alberta suggests a contribution from different sources or from different lithological horizons in the original source area. The absence of primary intragrain inhomogeneities in the gold nuclei points in favour of an origin from multiple sources. The primary deposits are believed to have been completely removed by erosion during the first stages of uplift of the Rocky Mountains.

Another point to remember is that the well-known stretches of the rivers where sand bars gives good colors lie approximately where the old bedrock channels intersect the present river channels (Fig. 29).

All these facts point in favour of a source area, for the gold, in the mountains drained in Cretaceous times by the rivers flowing from the west. Substantial amounts of detrital gold was probably transported by these rivers into the deltaic/marine environments near the river mouths (Late Albian Mowry

Sea?) and, in order to be transported in such low-energy environments, the gold particles were originally very fine-grained, probably also in colloidal states.

The placer gold in Alberta is the result of many cycles of river erosion and deposition, further complicated by glaciation (Fig. 30).

As far as the variation in size and shape is concerned, an average increase in Corey factors was determined (for the gold from the North Saskatchewan River)as the equivalent diameter increases, which means increasing flattening for decreasing size of the grains.

In the Athabasca River, where the grains are in the average smaller than in the North Saskatchewan River, two opposite trends were found to exist for grains of the same size class (Mesh+230). This is due to the presence of two varieties of grains of this size: the flakey variety and the sandwiched variety. The former is more difficult to recover with mecanical devices and this causes an apparent increase in Corey factors for the smallest fractions recovered with sluices, jigs and shaking tables. Most of the flakey gold is lost to the tailings. This is a point to keep in mind if gold is to be recovered in Alberta since the very small platy variety of gold particles represents at least 50-70 % of the gold present in the sand bars of the rivers studied. The efficiency of gravity devices in recovering flour gold is very low, therefore other methods such as flotation are suggested, not only for the very high efficiency of this technique but also for the reduced environmental problems and the cleaner concentrates obtained, suitable for direct smelting.

V. Plates

Plate 20 and Plates 27 to 29 were taken with the ARL SEMQ of the Department of Geology. (15 kV, 0.15 x 10^{-7}Amp).

Plates 21 to 26 were taken with the ISI 60 SEM of the Department of Engineering. (30 kV, 160 x 10^{-4}Amp).

Plates 30 to 33 were taken with the Cambridge Stereoscan 150 of the Department of Entomology.

COLOURED PICTURES
Images en couleur

Plate 1.1 (top): Sluice-box in operation.
Plate 1.2: Sluice-box ready to be carried: all the tools are stored inside.

COLOURED PICTURES
Images en couleur

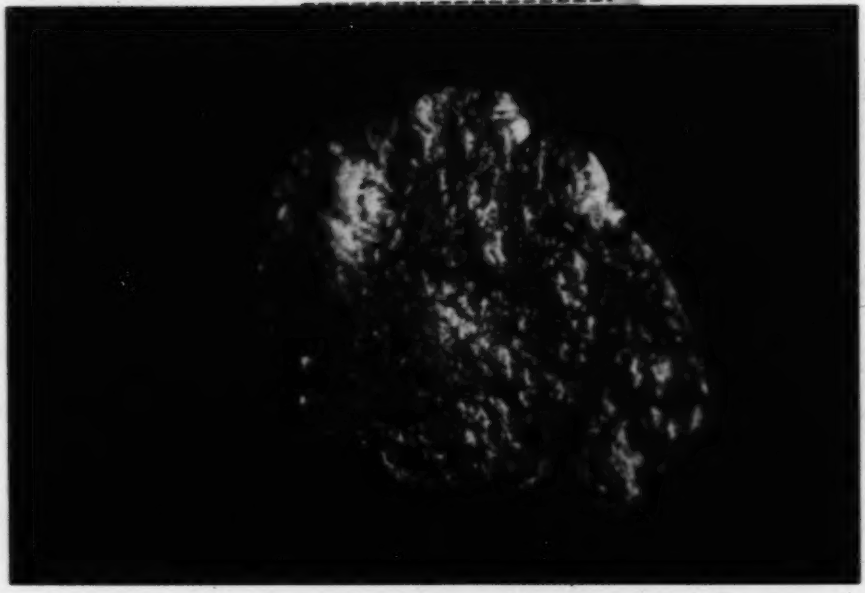
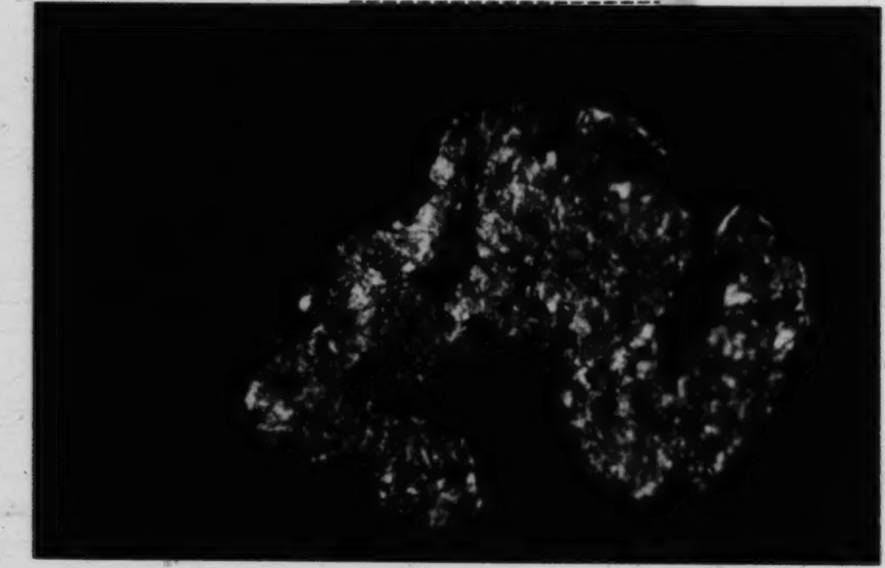


Plate 2.1 (top): Gold grain (from the N. Saskatchewan River) with typical rounded shape and color (gold-rich alloy). Mag. x100.
Plate 2.2: Gold grain (from the N. Saskatchewan River), light-yellow to orange in color. Mag. x80.

COLOURED PICTURES
Images en couleur

Plate 3.1 (top): Gold grain (from the Athabasca River showing impurities, inclusions and typical morphological features. Mag. x50.
Plate 3.2: Detail of the grain in Plate 3.1. Mag. x75.

COLOURED PICTURES
Images en couleur



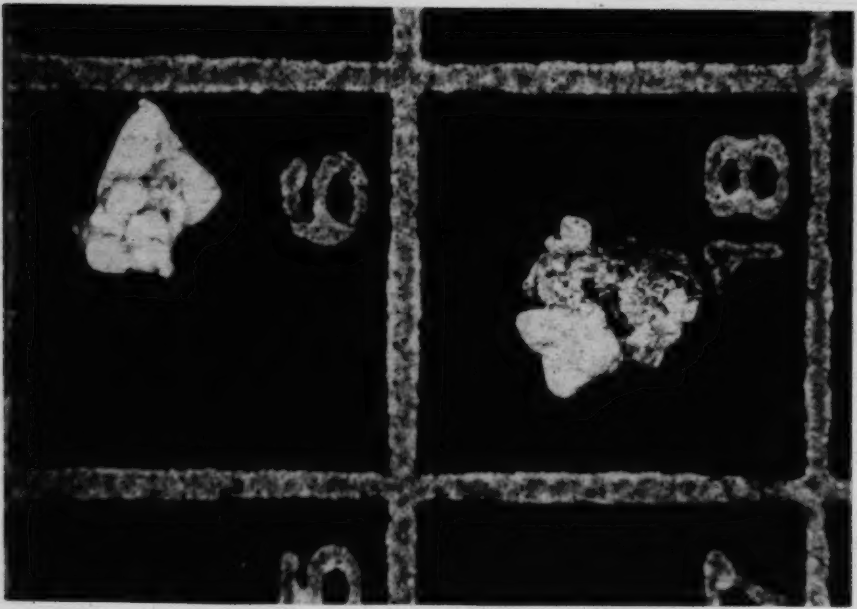


Plate 4.1 (top): Wire-like grain (N. Saskatchewan River). Mag. x80.
Plate 4.2: Amalgamated gold. Mag. x20.

COLOURED PICTURES
Images en couleur

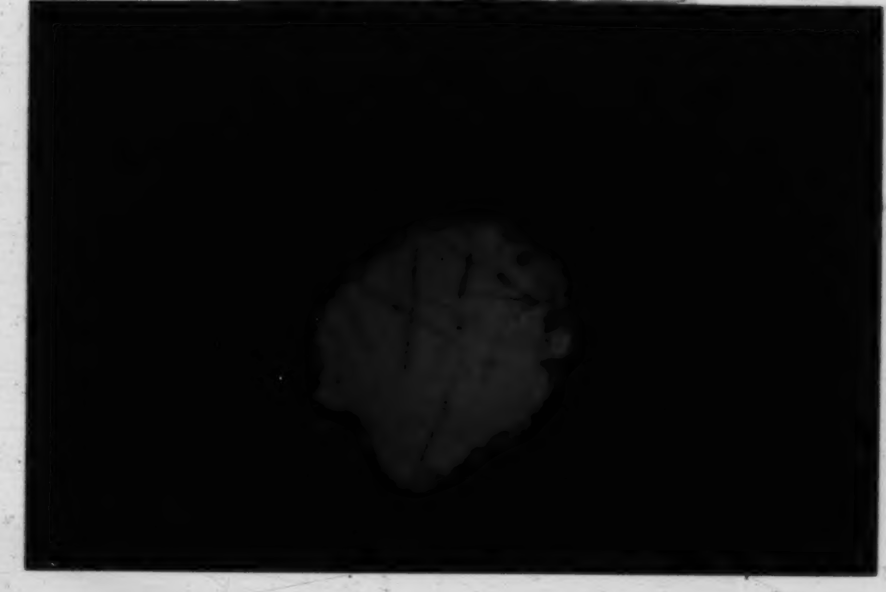


Plate 5.1 (top): Polished section of grain 18-2MCP. Mag. x500.
Plate 5.2: Polished section of grain 2-2MCP. Mag. x500.

COLOURED PICTURES
Images en couleur

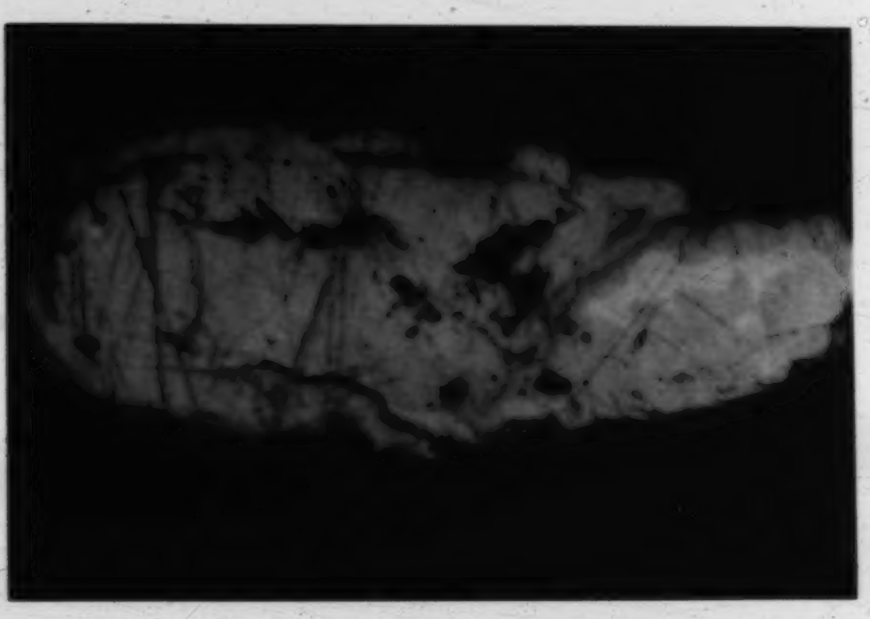
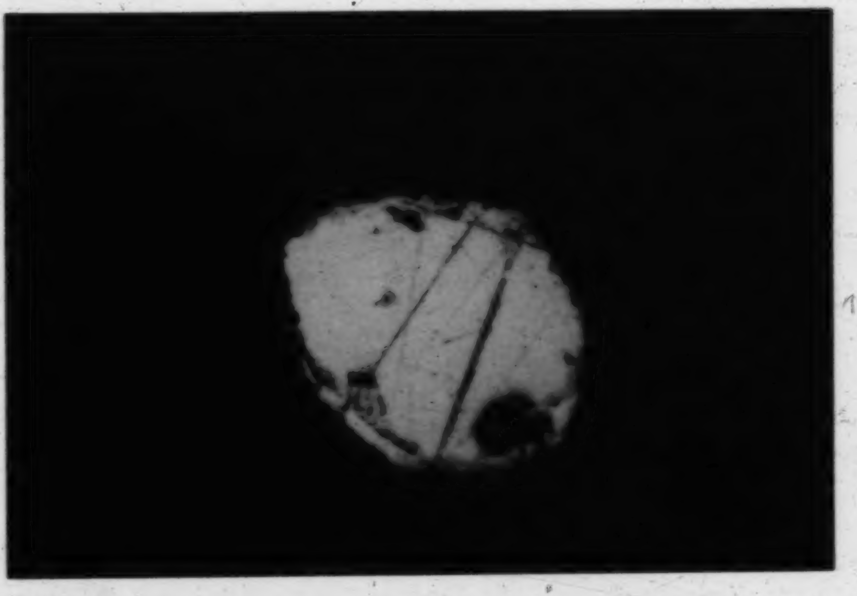


Plate 6.1 (top): Polished section of grain 1-2MCP. Mag. x500.
Plate 6.2: Polished section of grain 2-2M230. Mag. x500.

COLOURED PICTURES
Images en couleur

Plate 7.1 (top): Polished section of grain 46-26M120. Mag. x200.
Plate 7.2: Detail of grain in Plate 7.1. Mag. x500.



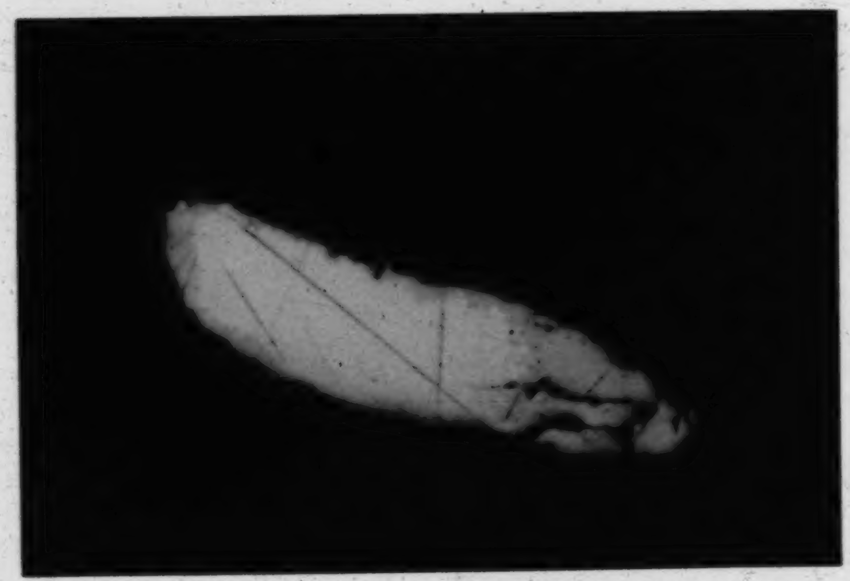
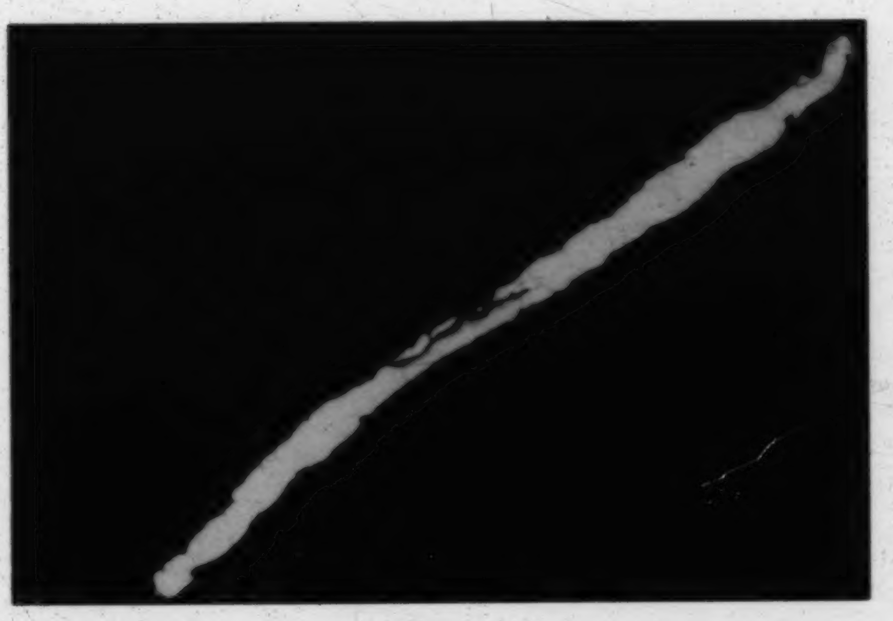


Plate 8.1 (top): Polished section of typical toroid-like gold grain. Mag. x200.
Plate 8.2: Polished section of grain 12-24M60. Mag. x200.



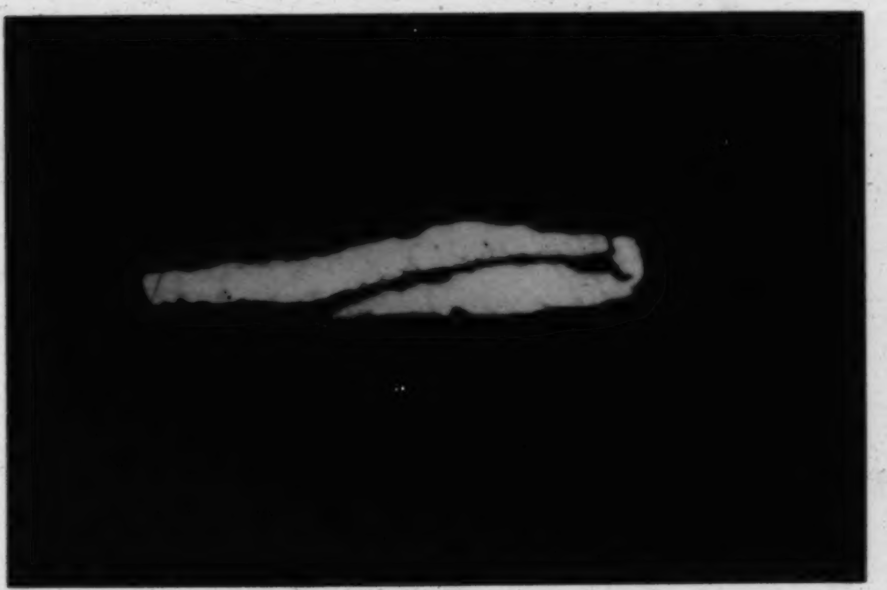
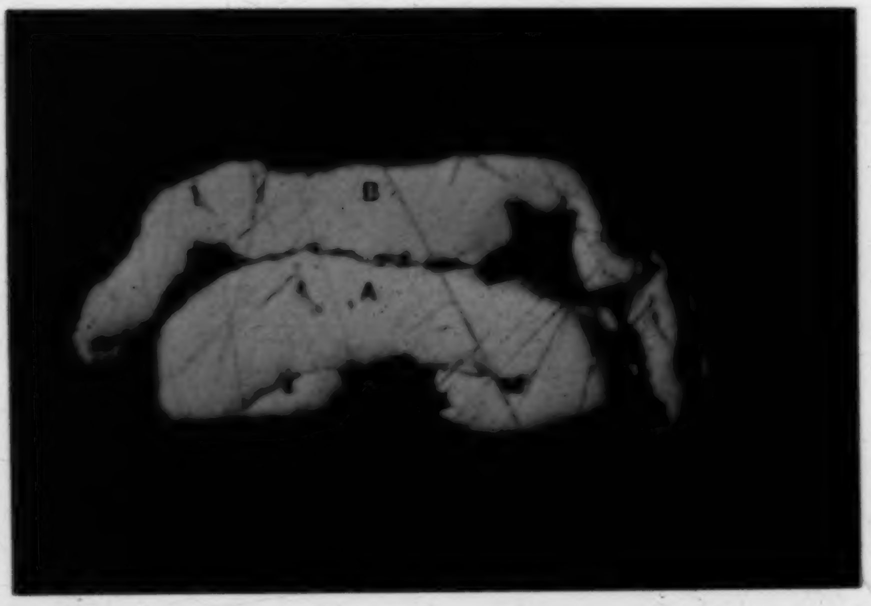


Plate 9.1 (top): Polished section of grain 57-25M60. Mag. x100.
Plate 9.2: Polished section of grain 56-25M60. Mag. x100.



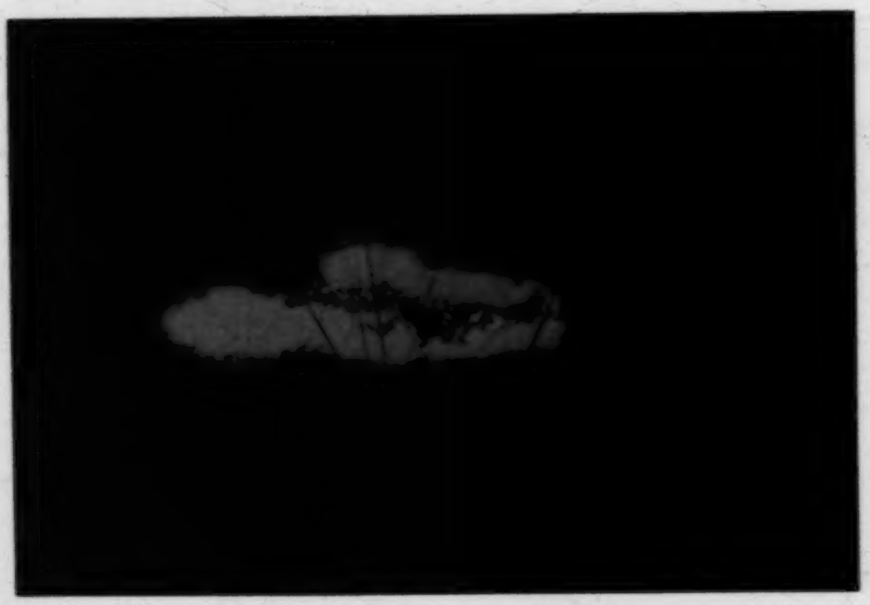


Plate 10.1 (top): Polished section of grain 19/A/B-24M60. Mag. x200.
Plate 10.2: Polished section of grain 35-26M120. Mag. x200.

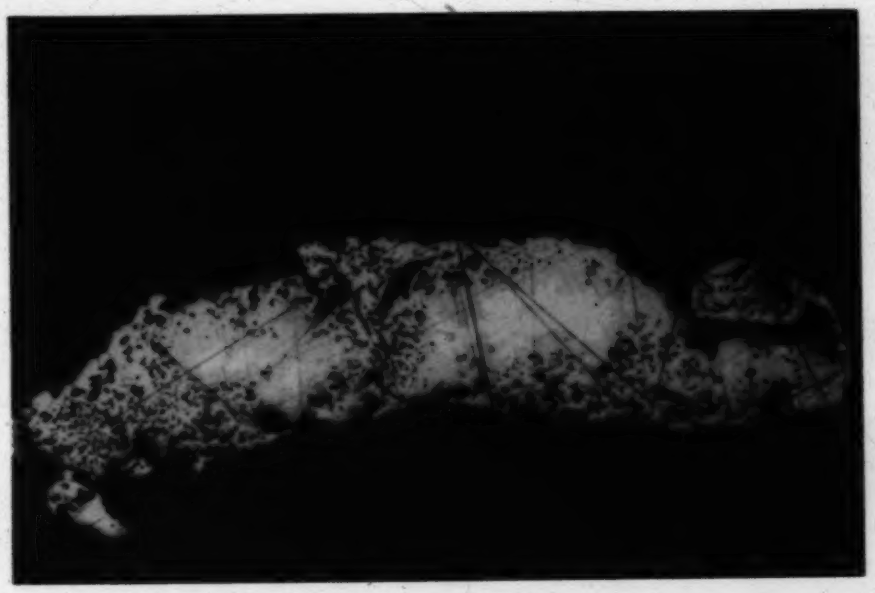
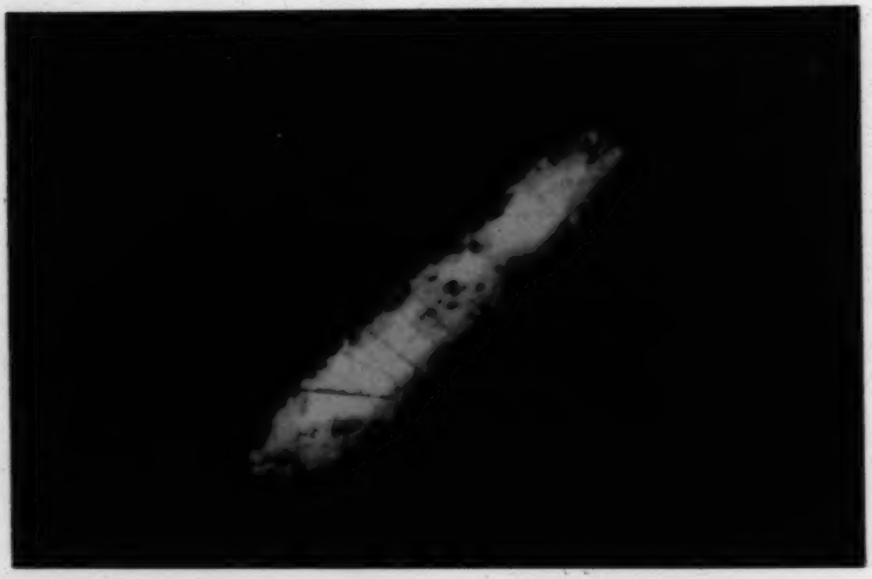


Plate 11.1 (top): Polished section of grain 6-19M60. Mag. x100.
Plate 11.2: Polished section of grain 1-26M35 (detail). Mag. x200.



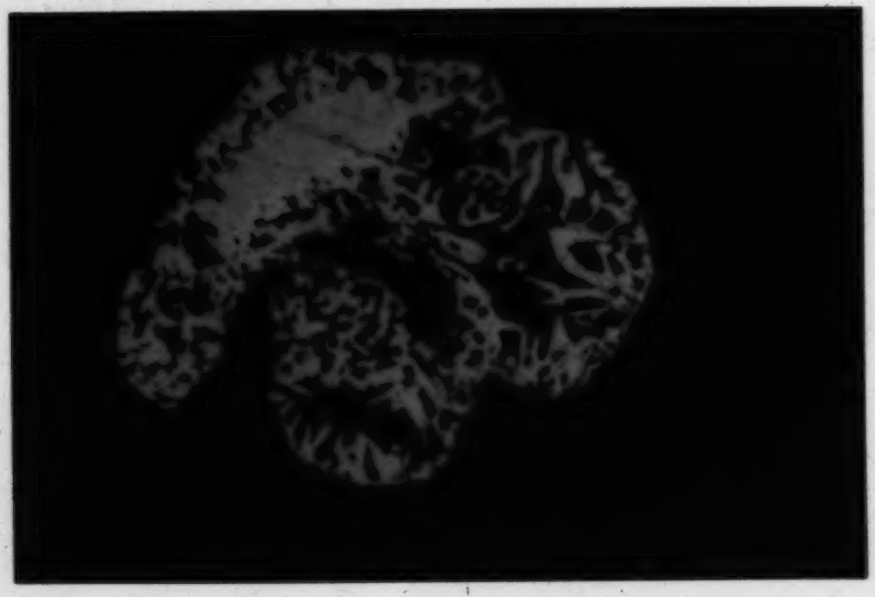
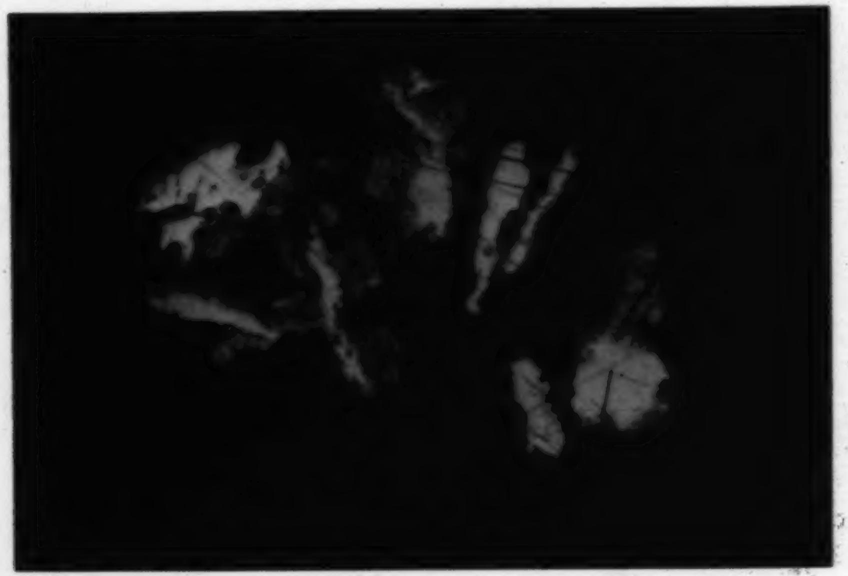


Plate 12.1 (top): Polished section of grain 19-28M120. Mag. x200.
Plate 12.2: Polished section of grain 12-24M120. Mag. x500.



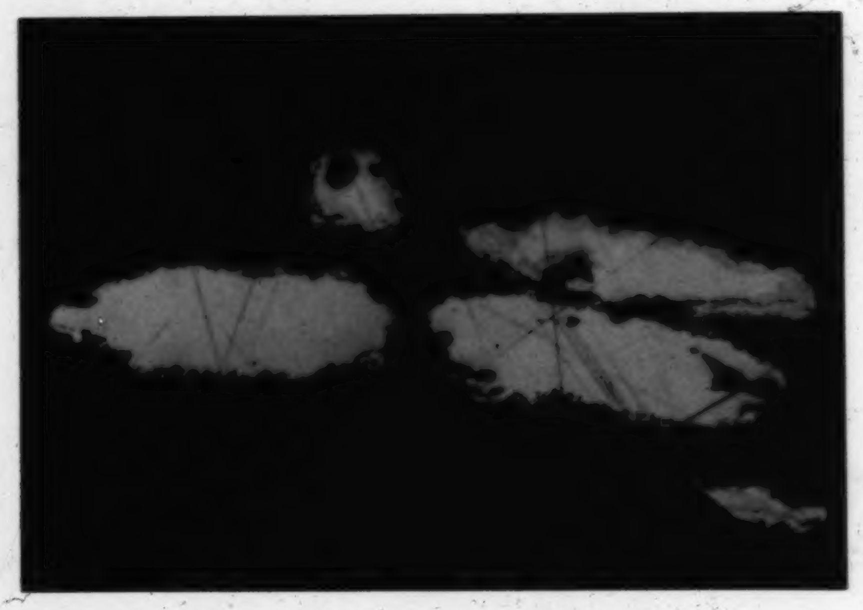


Plate 13.1 (top): Polished section of grain 15/A/B/C/D-20M60. Mag. x100.
Plate 13.2: Amalgamated gold grain 21A/B/C/D/E-28M120. Mag. x200.

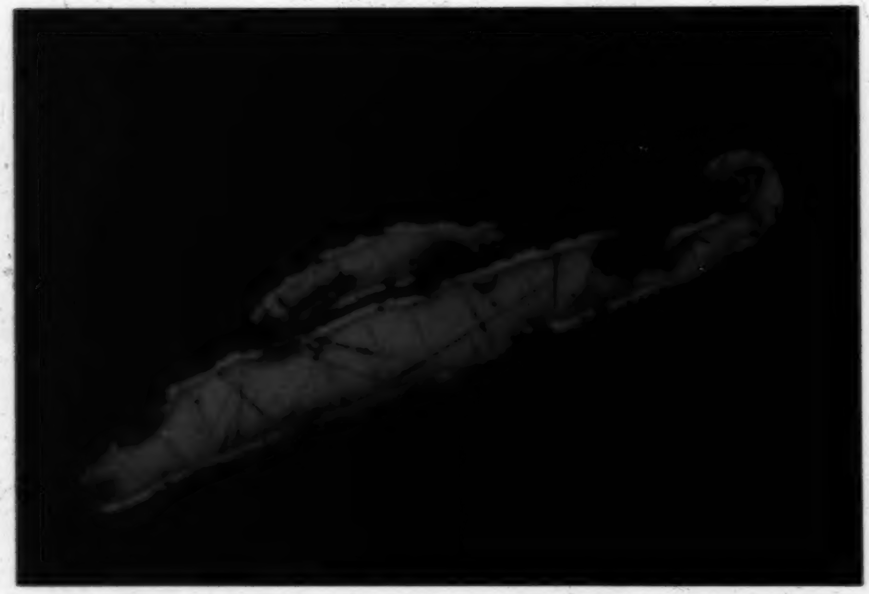


Plate 14: Polished section of grain 22-28M120 showing a pale rim of amalgam. Mag. x200.

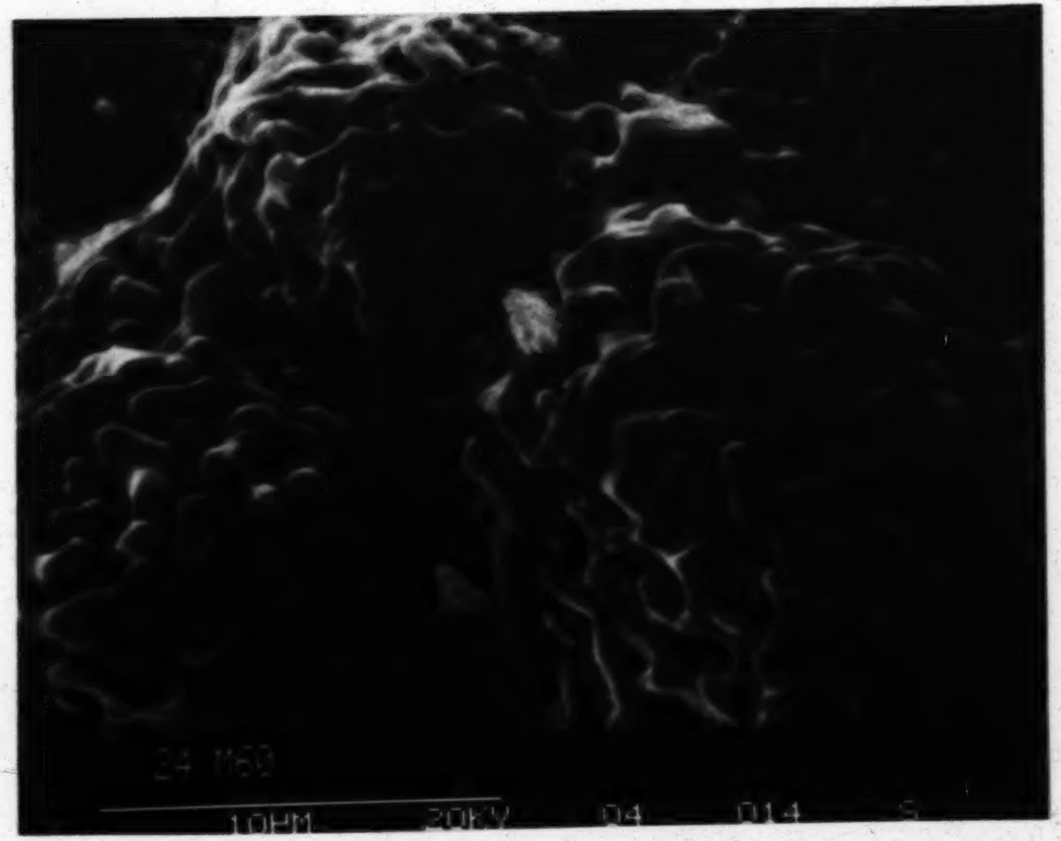

24 M60
10UM
20KV
04
014
S

Plate 15: Scanning electron photomicrograph of gold filaments. Detail of grain 24M60-07 in Plate 31.3.

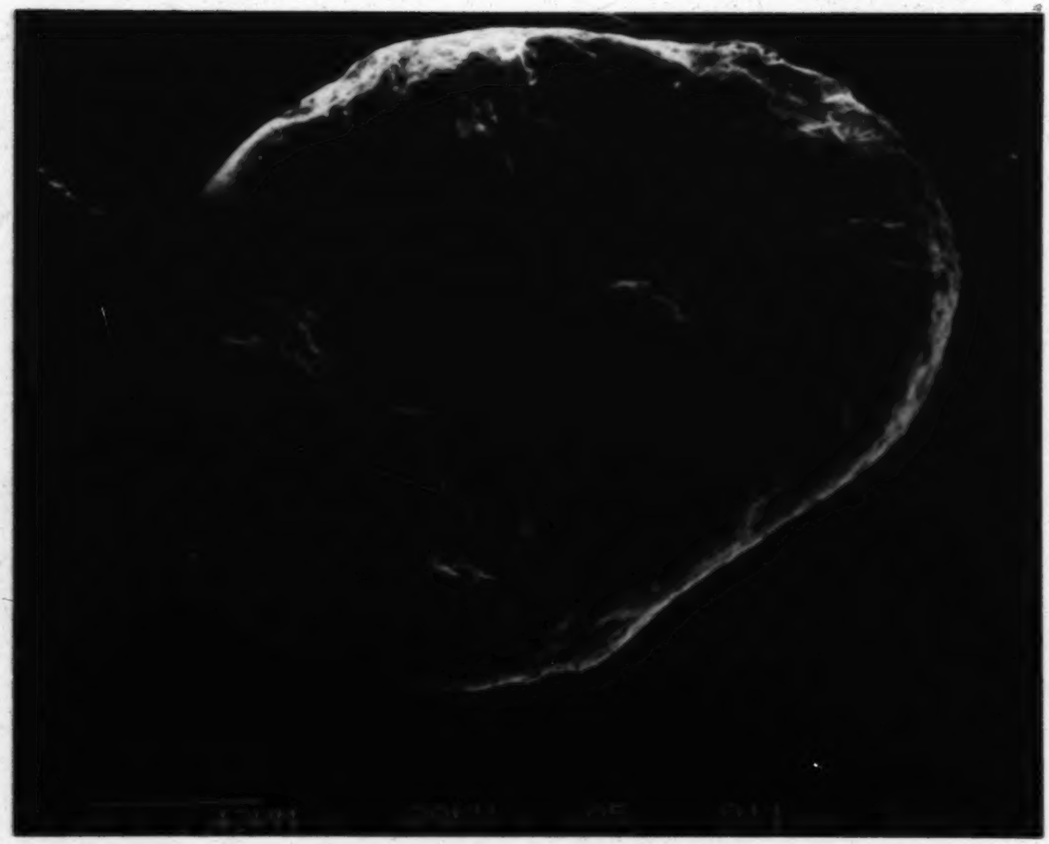


Plate 16: Scanning electron photomicrograph of a gold toroid with quartz inclusions (Redwater River).

Plate 17: Scanning electron photomicrograph of gold grain 24M60-05.

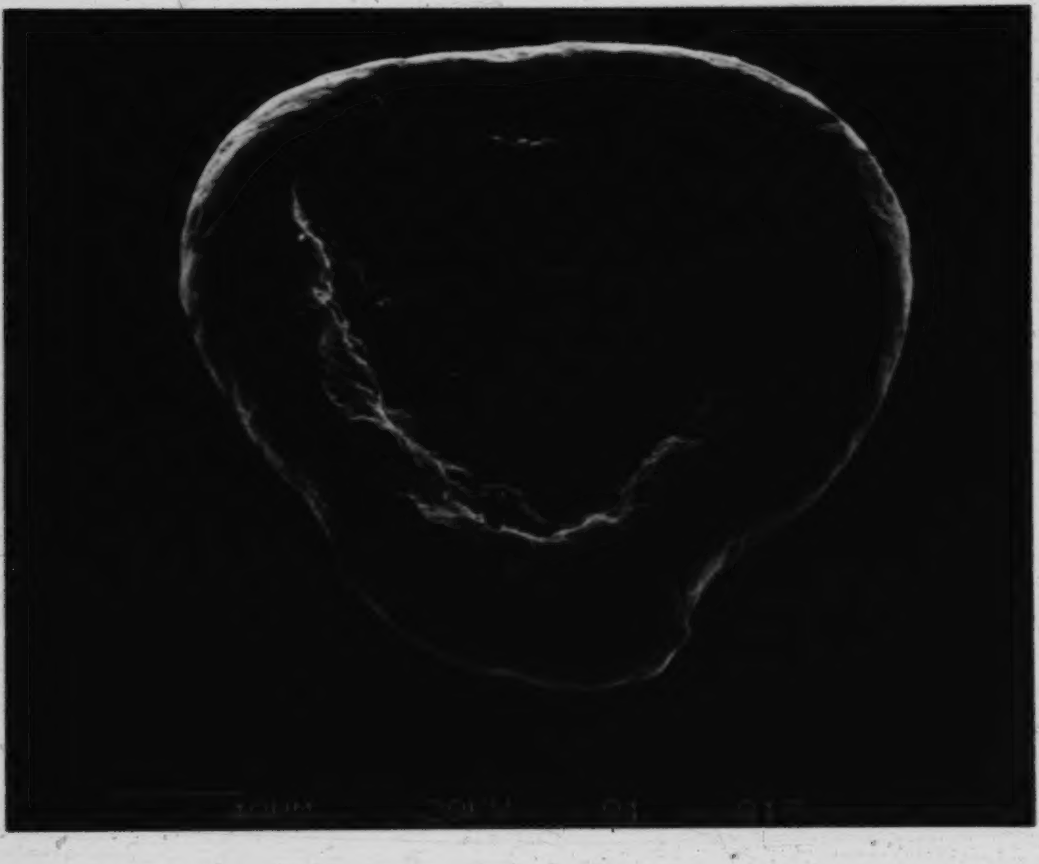


Plate 18: Scanning electron photomicrograph of a gold toroid (N. Saskatchewan River).

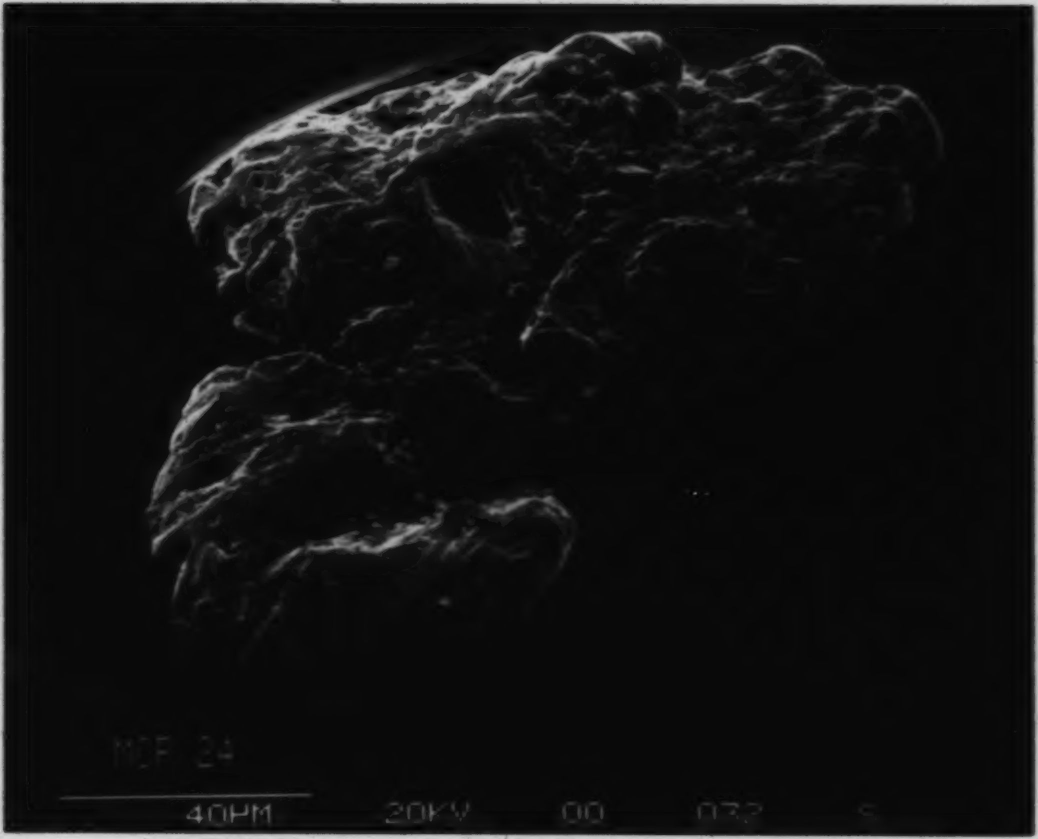

MCP 24
40PM
20KV
00
032
S

Plate 19: Scanning electron photomicrograph of gold grain 24MCP (N. Saskatchewan River).

Plate 20.1 (top): Backscattered electron photomicrograph of gold grain 61A/B/C/D/E-26M60.

Plate 20.2: Detail of Plate 20.1.

Plate 20

1

2

Plate 21.1 (top): Secondary electron photomicrograph of grain 16A/B-28M120.

Plate 21.2: Detail of Plate 21.1.

Plate 21

Plate 22.1 (top): Secondary electron photomicrograph of grain 22-28M120.

Plate 22.2: Secondary electron photomicrograph of grain 23A/B-28M120.

Plate 22

Plate 23.1 (top): Secondary electron photomicrograph of grain 21A/B/C/D/E-28M120.

Plate 23.2: Secondary electron photomicrograph of grain having a rim of amalgam.

Plate 23

Plate 24.1 (top): Secondary electron photomicrograph of grain 39-28M120.

Plate 24.2: Secondary electron photomicrograph of grain 39-28M120 (detail).

Plate 24

①

②

Plate 25.1 (top): Secondary electron photomicrograph of mount 28M120 containing 34 grains.

Plate 25.2 (left): X-ray spectrum of a gold grain containing Si and Hg impurities. The Hg peak overlaps the Au peak.

Plate 25.3 (right): X-ray spectrum of a gold grain containing Si and Fe. The Ag peak is also visible.

Plate 25

1

2

3

Plate 26.1 (top): X-ray spectrum of a grain of electrum. A pronounced Ag peak is visible.

Plate 26.2 (centre): X-ray spectrum of a grain of gold with low Ag content and some Hg.

Plate 26.3 (bottom): X-ray spectrum of a grain of gold showing the position of the Hg peaks.

Plate 26

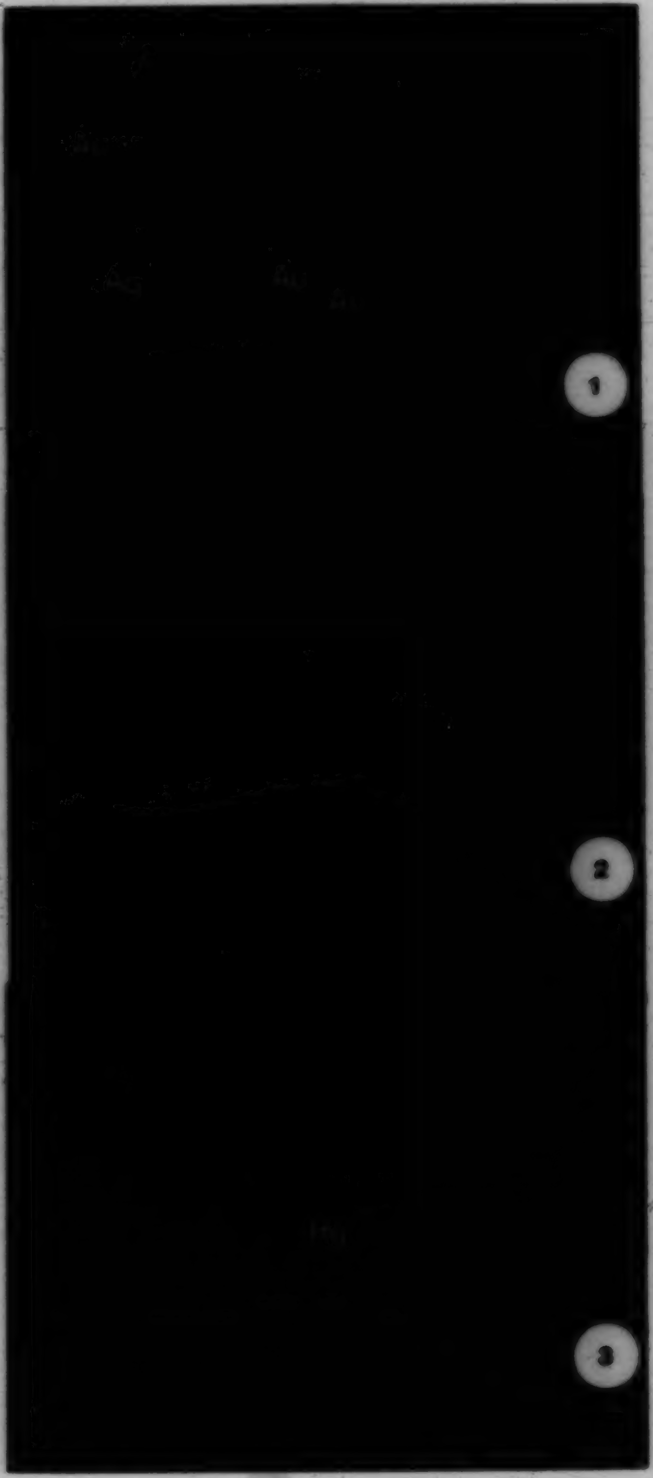


Plate 27.1: Ag X-ray (La) picture of gold grain 11-25M60.

Plate 27.2: Backscattered electron picture of a portion of grain 11-25M60.

Plate 27.3: Au X-ray (Ma) picture of grain 11-25M60.

Plate 27.4: Ag X-ray (La) picture of grain 11-25M60.

Plate 27

2

4

1

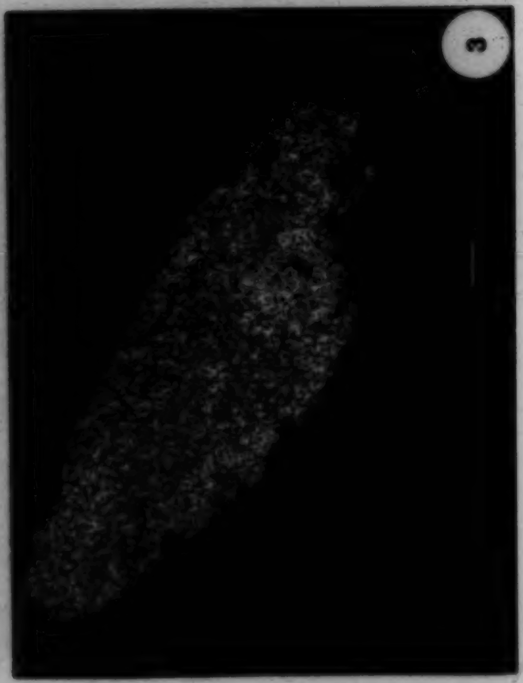

3

Plate 28.1: Backscattered electron picture of grain 3-33M230.

Plate 28.2: Backscattered electron picture of grain 3-33M23.

Plate 28.3: Ag X-ray (La) picture of grain 3-33M230.

Plate 28.4: Au X-ray (Ma) picture of grain 3-33M230.

Plate 28

Plate 29.1: Au X-ray (Ma) picture of grain 32-25M60.

Plate 29.2: Ag X-ray (La) picture of grain 32-25M60.

Plate 29

1

2

Plate 30.1: Scanning electron photomicrograph of a detrital gold grain (North Saskatchewan River).

Plate 30.2: Scanning electron photomicrograph of a detrital gold grain (North Saskatchewan River).

Plate 30.3: Scanning electron photomicrograph. Detail of grain in Plate 30.2.

Plate 30.4: Scanning electron photomicrograph. Detail of the gold grain in Plate 30.1.

Plate 30.5: Scanning electron photomicrograph. Detail of the gold grain in Plate 30.1.

Plate 30.6: Scanning electron photomicrograph. Detail of the gold grain in Plate 30.1.

Plate 30

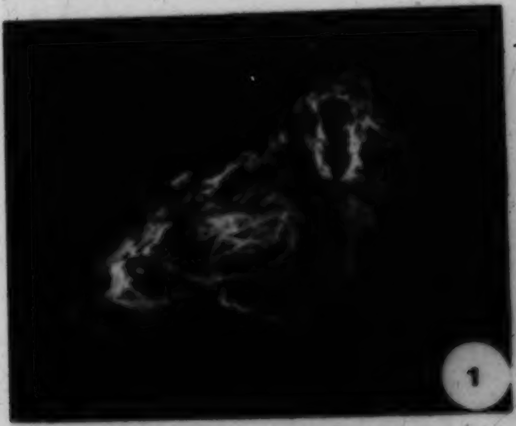


Plate 31.1: Scanning electron photomicrograph showing two gold grains held together by spongy, filamentous gold.

Plate 31.2: Same as Plate 31.1.

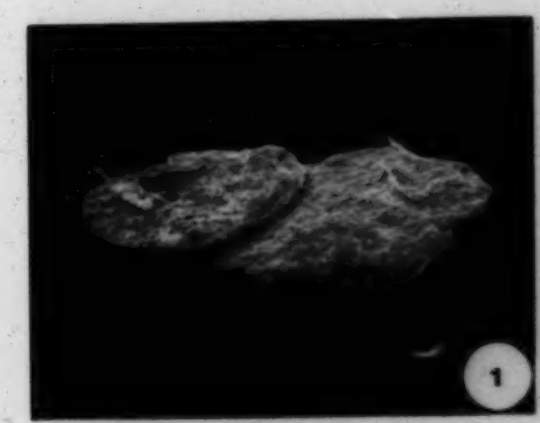
Plate 31.3: Scanning electron photomicrograph of a gold grain covered by filamentous gold.

Plate 31.4: Scanning electron photomicrograph showing a detail of the crust of filamentous gold covering the gold grain in Plate 31.3.

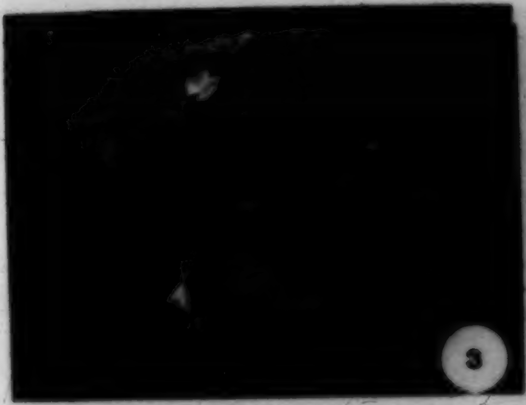
Plate 31.5: Scanning electron photomicrograph showing the texture of gold grains having patches of spongy material covering their surface.

Plate 31.6: Scanning electron photomicrograph of gold flakes held together by filamentous gold.

Plate 31


①

②


③

④

⑤

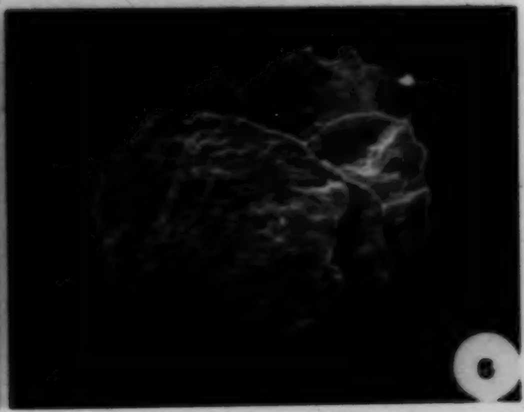

⑥

Plate 32.1: Scanning electron photomicrograph of a gold grain having folded edges and inclusions of other minerals.

Plate 32.2: Detail of the gold grain in Plate 32.1.

Plate 32.3: Scanning electron photomicrograph of a gold grain having the typical "sandwich" structure.

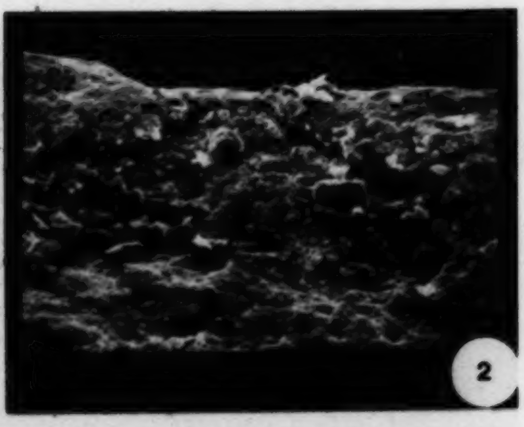
Plate 32.4: Scanning electron photomicrograph of folded gold grains held together by filamentous gold.

Plate 32.5: Scanning electron photomicrograph of a gold grain showing deformation structures and parallel scratching.

Plate 32.6: Scanning electron photomicrograph of a grain from locality 24 (N. Saskatchewan River). Mesh CP(=M-230).

Plate 32

1


2

3

4

5

6

Plate 33.1: Scanning electron photomicrograph of a gold grain from locality 5 (Athabasca River). Mesh+230.

Plate 33.2: Scanning electron photomicrograph of a grain from locality 5 (Athabasca River). Mesh+230.

Plate 33.3: Scanning electron photomicrograph of a gold grain from locality 2 (Athabasca River). Mesh+230.

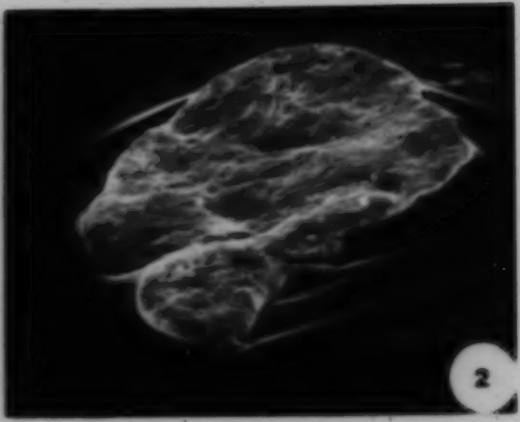
Plate 33.4: Scanning electron photomicrograph of a toroidal gold grain from locality 25 (N. Saskatchewan River). Mesh+120.

Plate 33.5: Scanning electron photomicrograph of a toroidal gold grain from locality 33 (Redwater River). Mesh+230.

Plate 33.6: Scanning electron photomicrograph of a gold grain from locality 33 (Redwater River). Mesh+230.

Plate 33

1


2

3

4

5

6

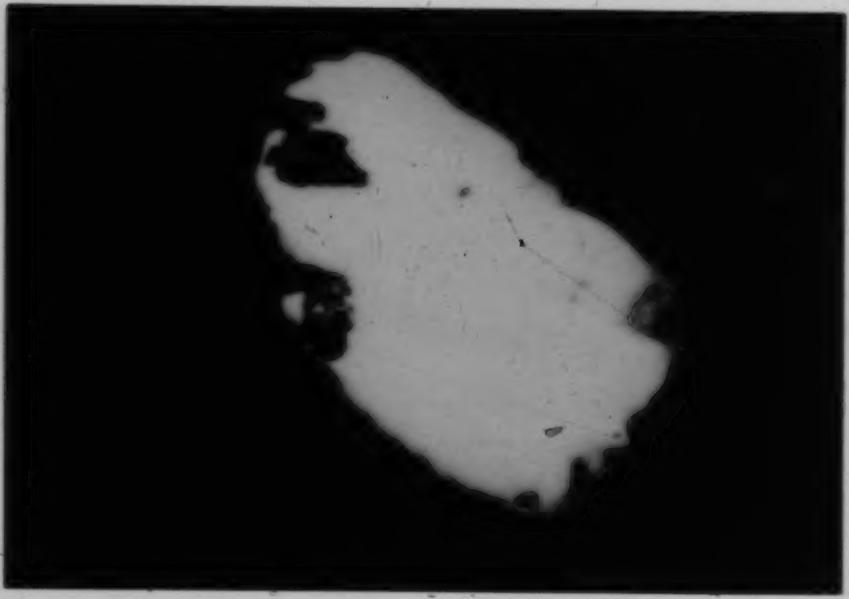
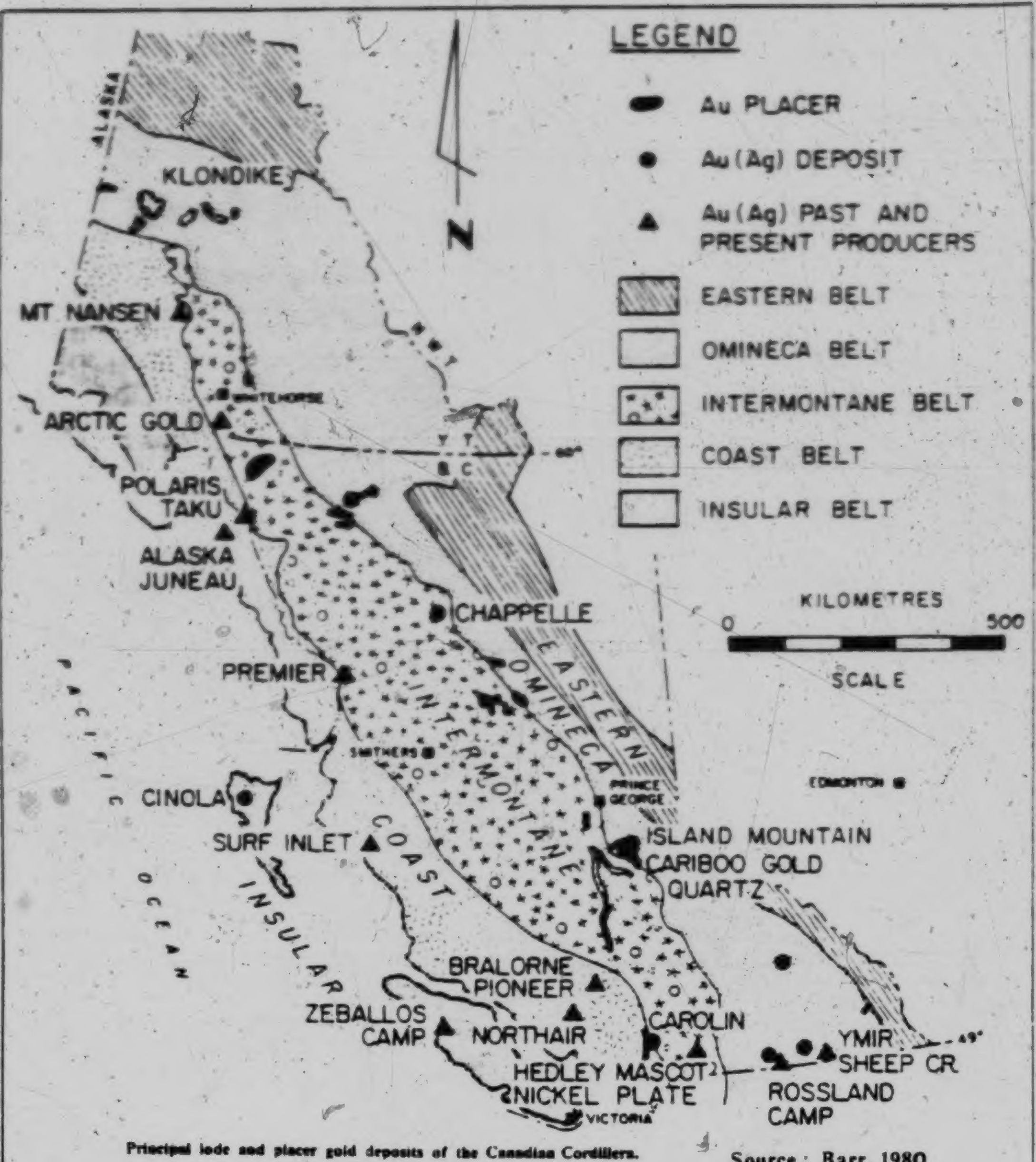


Plate 34.1 (top): Polished section of a native platinum grain (P7) from the N. Saskatchewan River. Mag. x500.
Plate 34.2: Polished section of two grains of scheelite from the N. Saskatchewan River. Mag. x100.

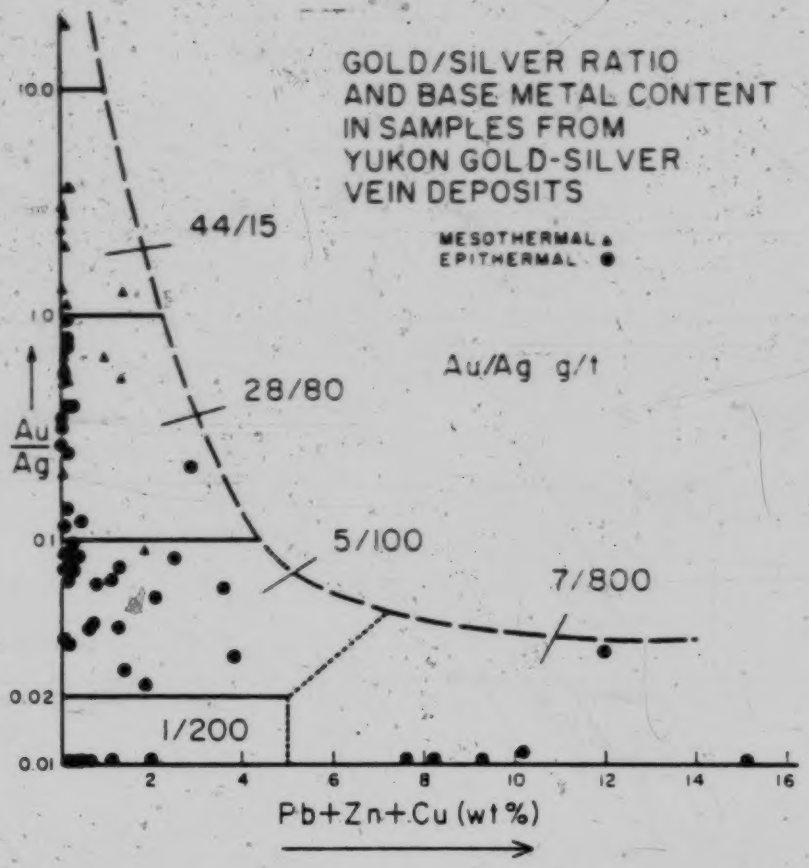
VI. Figures


LEGEND
Au PLACER
Au (Ag) DEPOSIT
Au (Ag) PAST AND PRESENT PRODUCERS
EASTERN BELT
OMINECA BELT
INTERMONTANE BELT
COAST BELT
INSULAR BELT
KILOMETRES
0
500
SCALE
N
ALASKA
KLONDIKE
MT NANSEN
WHITEHORSE
ARCTIC GOLD
POLARIS TAKU
ALASKA JUNEAU
Y.T.
B.C.
60°
CHAPPELLE
PREMIER
EASTERN
OMINECA
INTERMONTANE
SMITHERS
PRINCE GEORGE
EDMONTON
PACIFIC OCEAN
CINOLA
SURF INLET
COAST
INSULAR
ISLAND MOUNTAIN
CARIBOO GOLD QUARTZ
BRALORNE PIONEER
ZEBALLOS CAMP
NORTHAIR
CAROLIN
HEDLEY MASCOT
NICKEL PLATE
VICTORIA
YMIR
SHEEP CR.
ROSSLAND CAMP
49°

Principal lode and placer gold deposits of the Canadian Cordillera.

Source: Barr, 1980

Figure 1: Principal lode and placer gold deposits of the Canadian Cordillera



Plot of the gold-silver ratio on a log scale versus the weight per cent of base metals (Pb + Zn + Cu) on an arithmetic scale. Average gold and silver values (grams/tonne) are shown for five sub-areas. Samples depicted are from epithermal and mesothermal deposits only

Source: Barr, 1980

Figure 2: Gold/silver ratio and base metal content in samples from Yukon gold-silver vein deposits

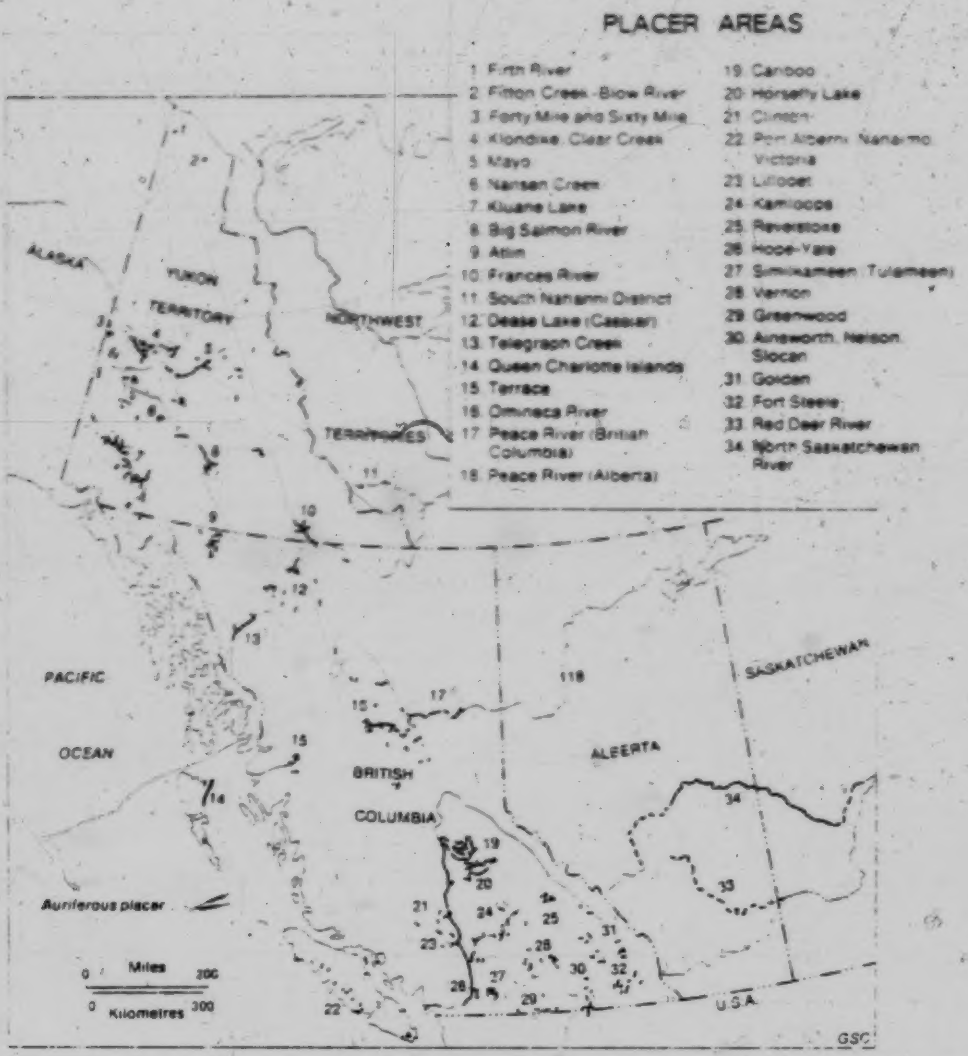
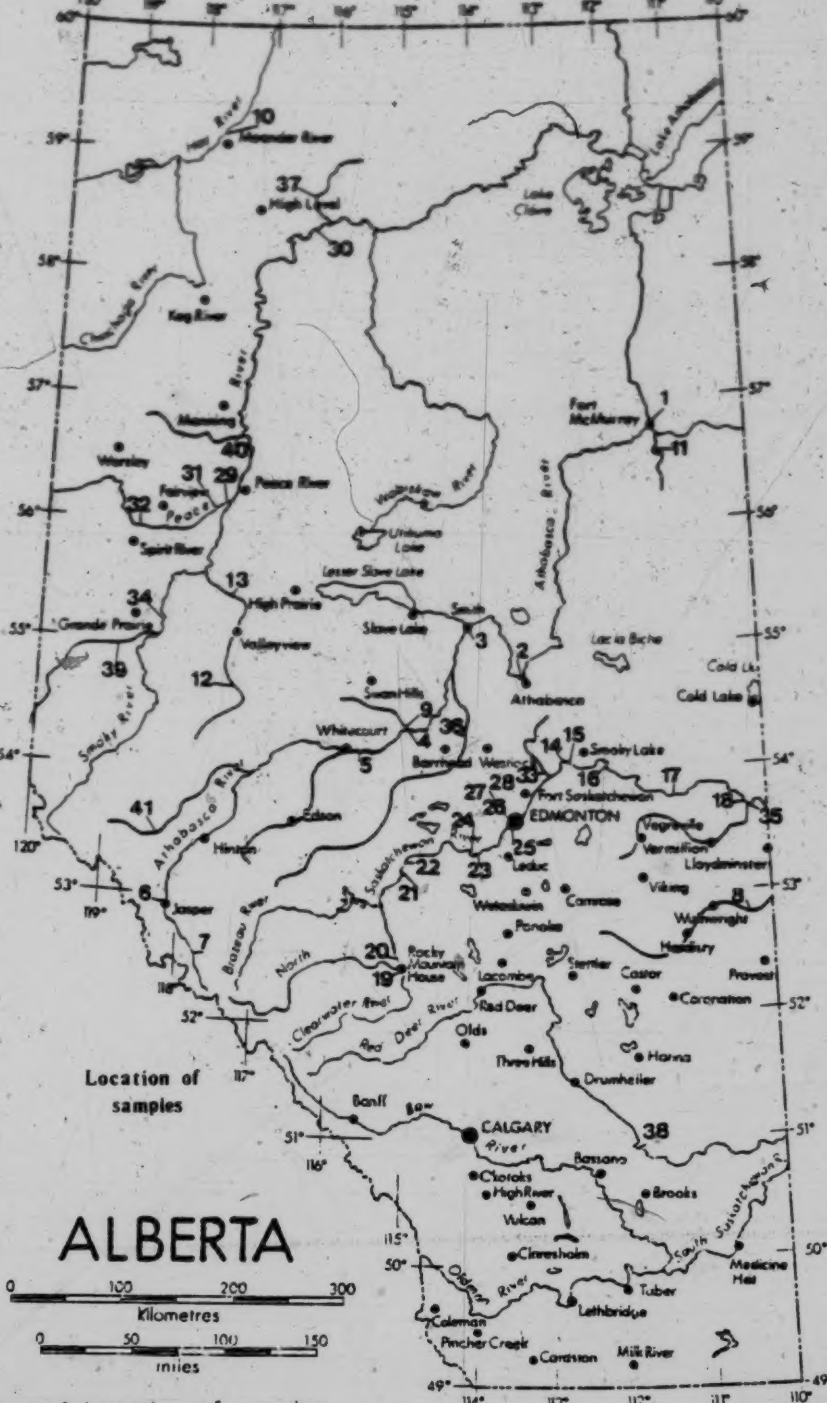

PLACER AREAS
1 Firth River
2 Fitton Creek - Blow River
3 Forty Mile and Sixty Mile
4 Klondike, Clear Creek
5 Mayo
6 Nansen Creek
7 Kluane Lake
8 Big Salmon River
9 Atlin
10 Frances River
11 South Nahanni District
12 Dease Lake (Cassiar)
13 Telegraph Creek
14 Queen Charlotte Islands
15 Terrace
16 Omineca River
17 Peace River (British Columbia)
18 Peace River (Alberta)
19 Cariboo
20 Horsefly Lake
21 Clinton
22 Port Alberni, Nanaimo, Victoria
23 Lillooet
24 Kamloops
25 Revelstoke
26 Hope-Yale
27 Similkameen (Tulameen)
28 Vernon
29 Greenwood
30 Ainsworth, Nelson, Slocan
31 Golden
32 Fort Steele
33 Red Deer River
34 North Saskatchewan River
ALASKA
YUKON TERRITORY
NORTHWEST TERRITORIES
PACIFIC OCEAN
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
U.S.A.
Auriferous placer
Miles 0 300
Kilometres 0 300
GSC

Figure 3: Placer gold district in western Canada

SOURCE: BOYLE, 1979



ALBERTA
Location of samples
0 100 200 300
Kilometres
0 50 100 150
miles
120° 119° 118° 117° 116° 115° 114° 113° 112° 111° 110°
60° 59° 58° 57° 56° 55° 54° 53° 52° 51° 50° 49°
Hay River
Meander River
High Level
Keg River
Manning
Peace River
Worsley
Fairview
Spirit River
Grande Prairie
Smoky River
Valleyview
High Prairie
Lesser Slave Lake
Slave Lake
Smith
Swan Hills
Whitecourt
Barrhead
Westlock
Edson
Hinton
Jasper
Athabasca River
Athabasca
Lake Athabasca
Lake Claire
Fort McMurray
Wabasca River
Utikuma Lake
Lac la Biche
Cold Lake
Smoky Lake
Fort Saskatchewan
EDMONTON
Leduc
Vegreville
Vermilion
Lloydminster
Viking
Camrose
Wetaskiwin
Wainwright
Hardisty
Ponoka
Provost
Rocky Mountain House
Lacombe
Stettler
Castor
Coronation
Red Deer
Olds
Three Hills
Hanna
Drumheller
Brazeau River
North Saskatchewan River
Clearwater River
Red Deer River
Banff
Bow River
CALGARY
Bassano
Brooks
Okotoks
High River
Vulcan
Claresholm
South Saskatchewan R.
Medicine Hat
Oldman River
Taber
Lethbridge
Coleman
Pincher Creek
Cardston
Milk River
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41

Figure 4: Location of samples

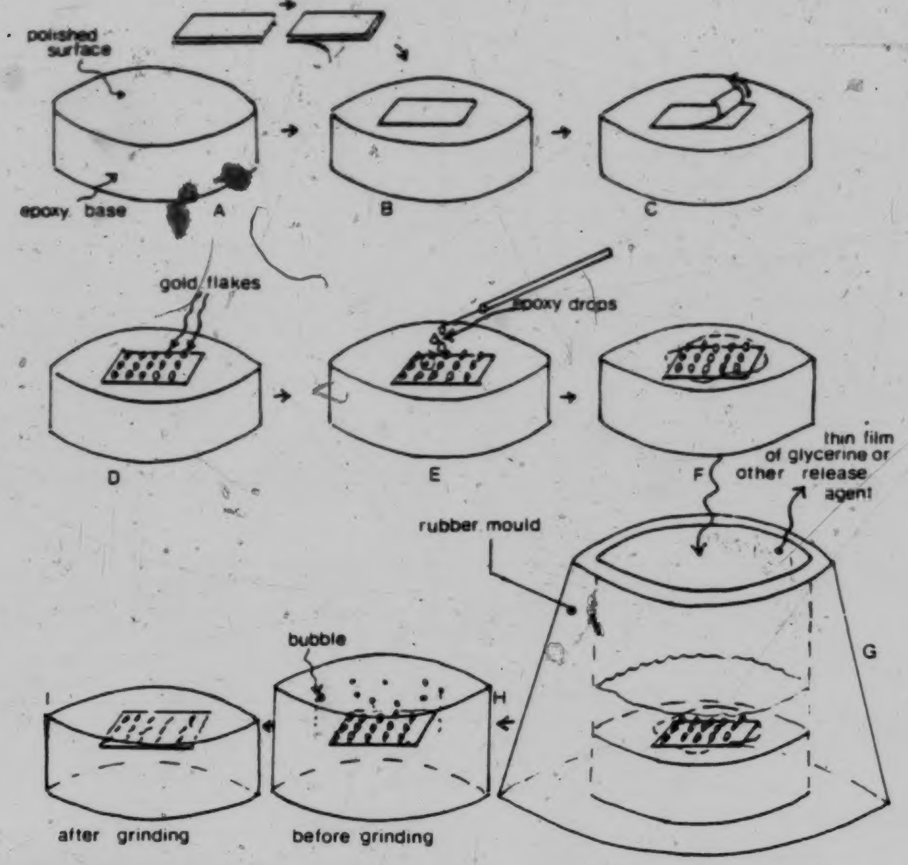

polished surface
epoxy base
A
B
C
gold flakes
epoxy drops
D
E
F
thin film of glycerine or other release agent
rubber mould
G
bubble
H
I
after grinding
before grinding

Figure 5: Specimen mounting procedure. Method 1

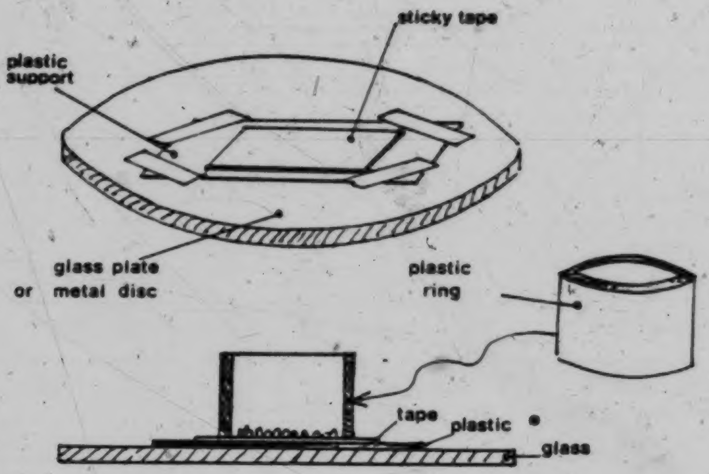

sticky tape
plastic support
glass plate
or metal disc
plastic ring
tape
plastic
glass

Figure 6: Specimen mounting procedure. Method 2

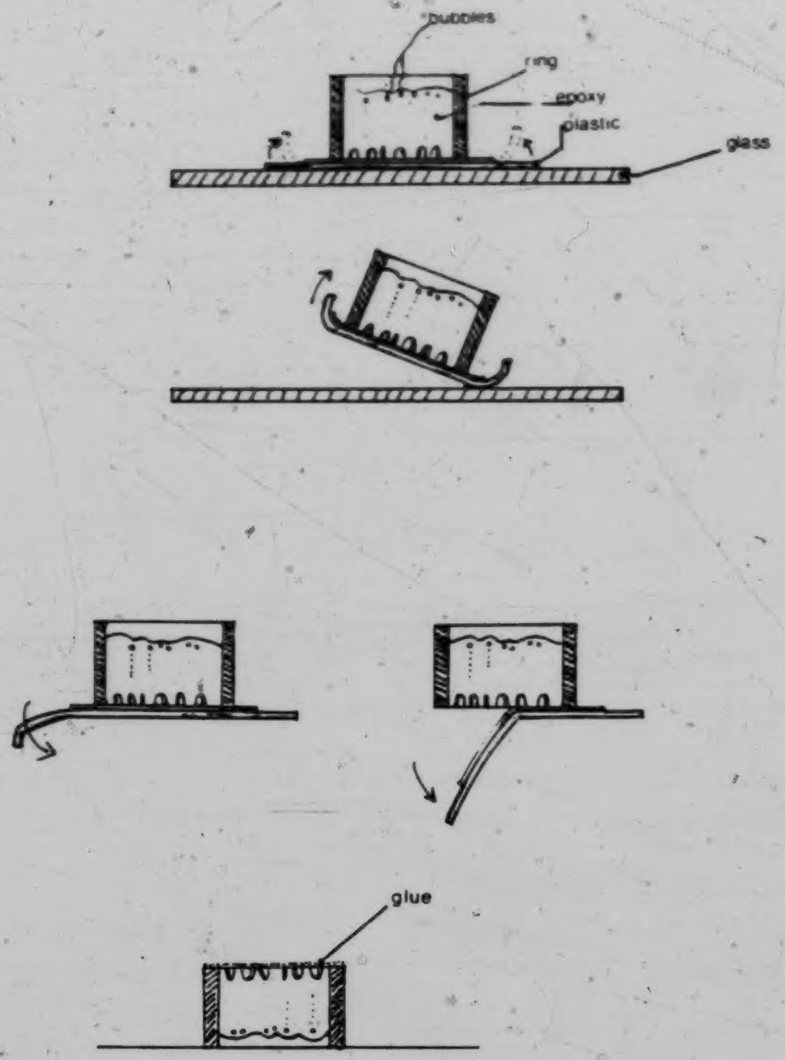

bubbles
ring
epoxy
plastic
glass
glue

Figure 7: Specimen mounting procedure. Method 2

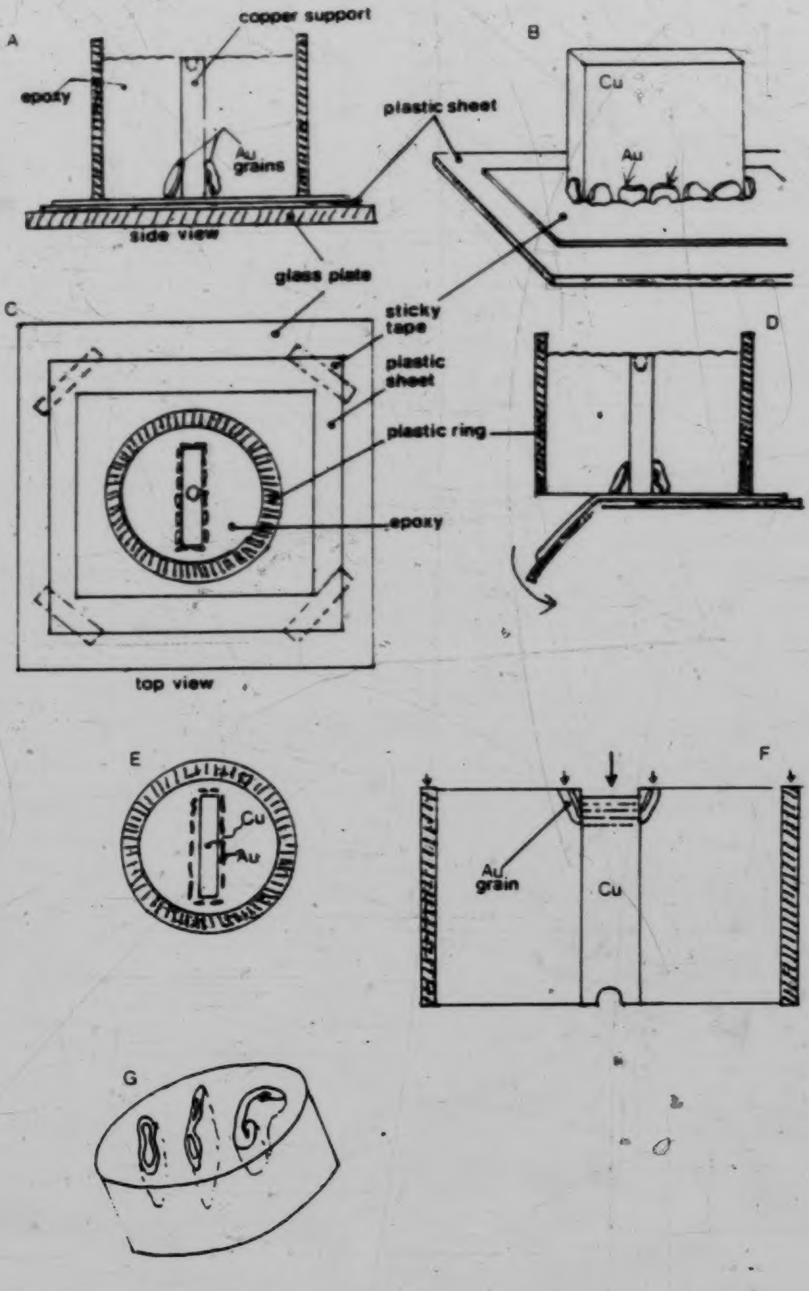

A
copper support
epoxy
Au grains
side view
B
Cu
plastic sheet
Au
glass plate
C
sticky tape
plastic sheet
plastic ring
epoxy
top view
D
E
Cu
Au
F
Au grain
Cu
G

Figure 8: Specimen mounting procedure. Method 3

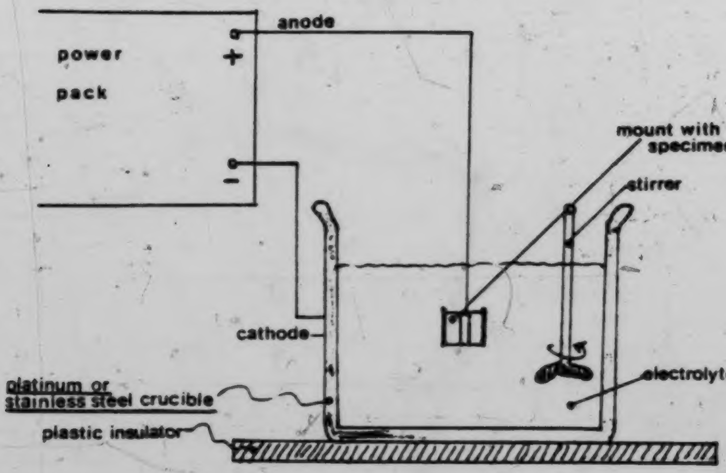

anode
power
pack
+
−
mount with specimen
stirrer
cathode
electrolyte
platinum or stainless steel crucible
plastic insulator

Figure 9: Electrolytic cell for electropolishing

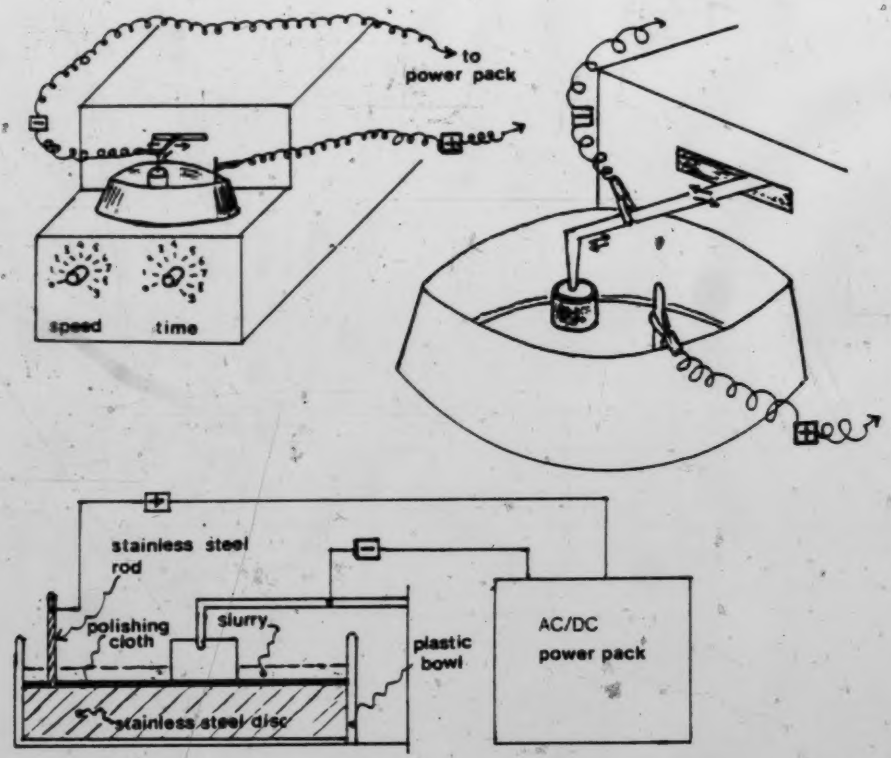
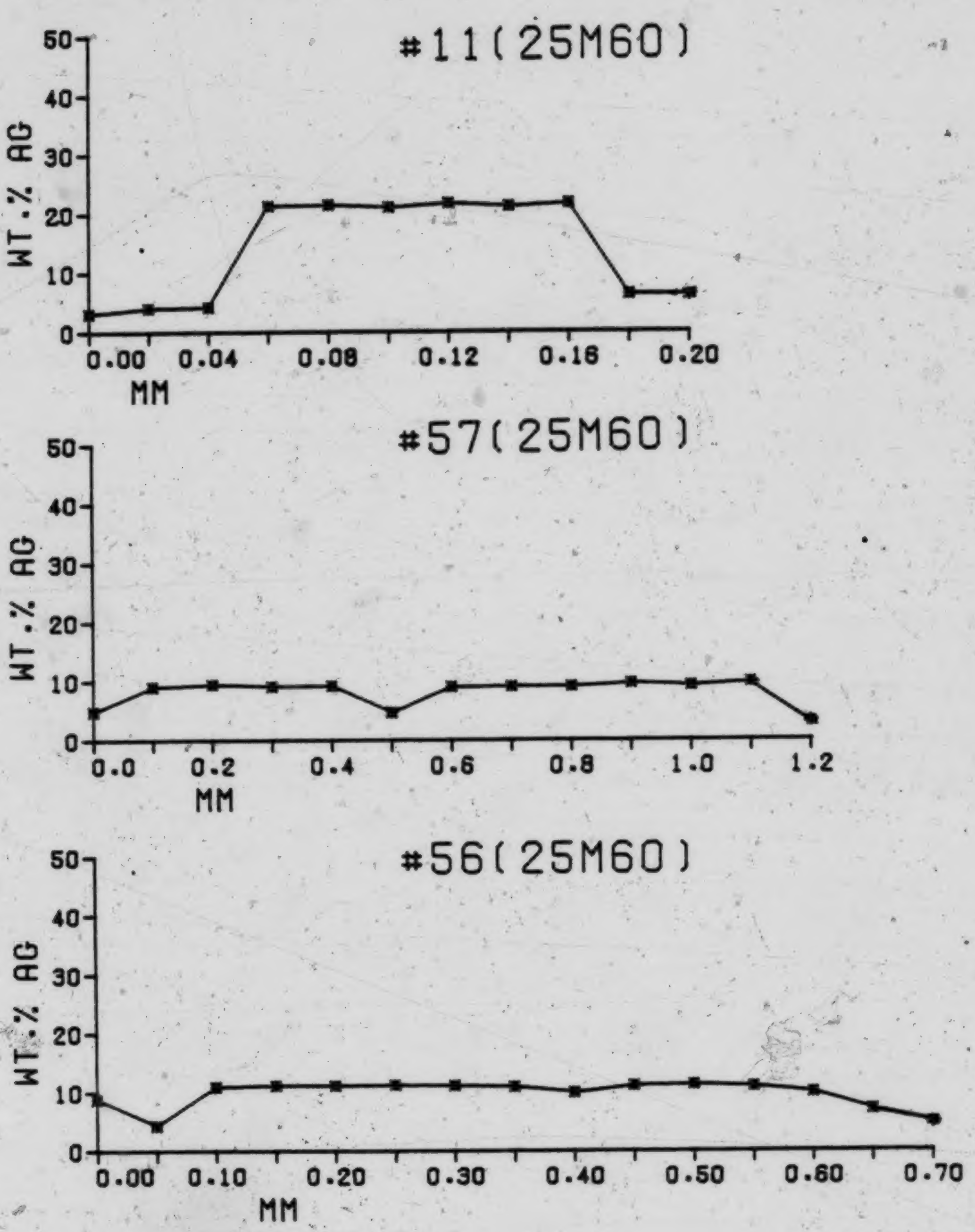

to power pack
speed
time
+
−
stainless steel rod
polishing cloth
slurry
plastic bowl
AC/DC power pack
stainless steel disc
SCHEMATIC OF ELECTROMECHANICAL POLISHING AND ETCHING

Figure 10: Schematic of electromechanical polishing and etching

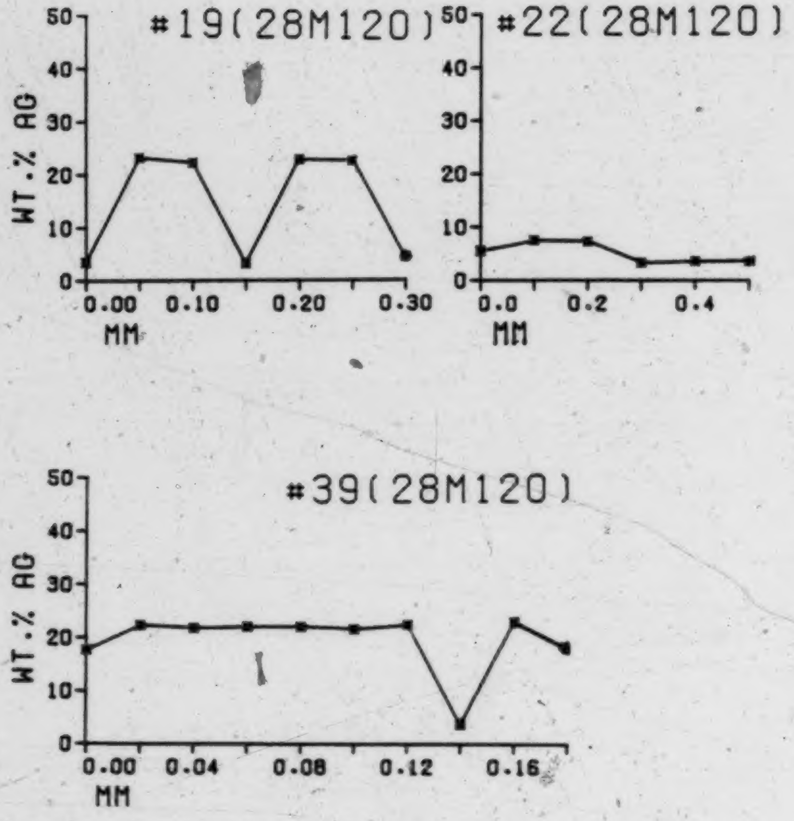
3

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6



EL.PROBE STEP-SCANNING PROFILES

Figure 11



EL.PROBE STEP-SCANNING
PROFILES

Figure 12

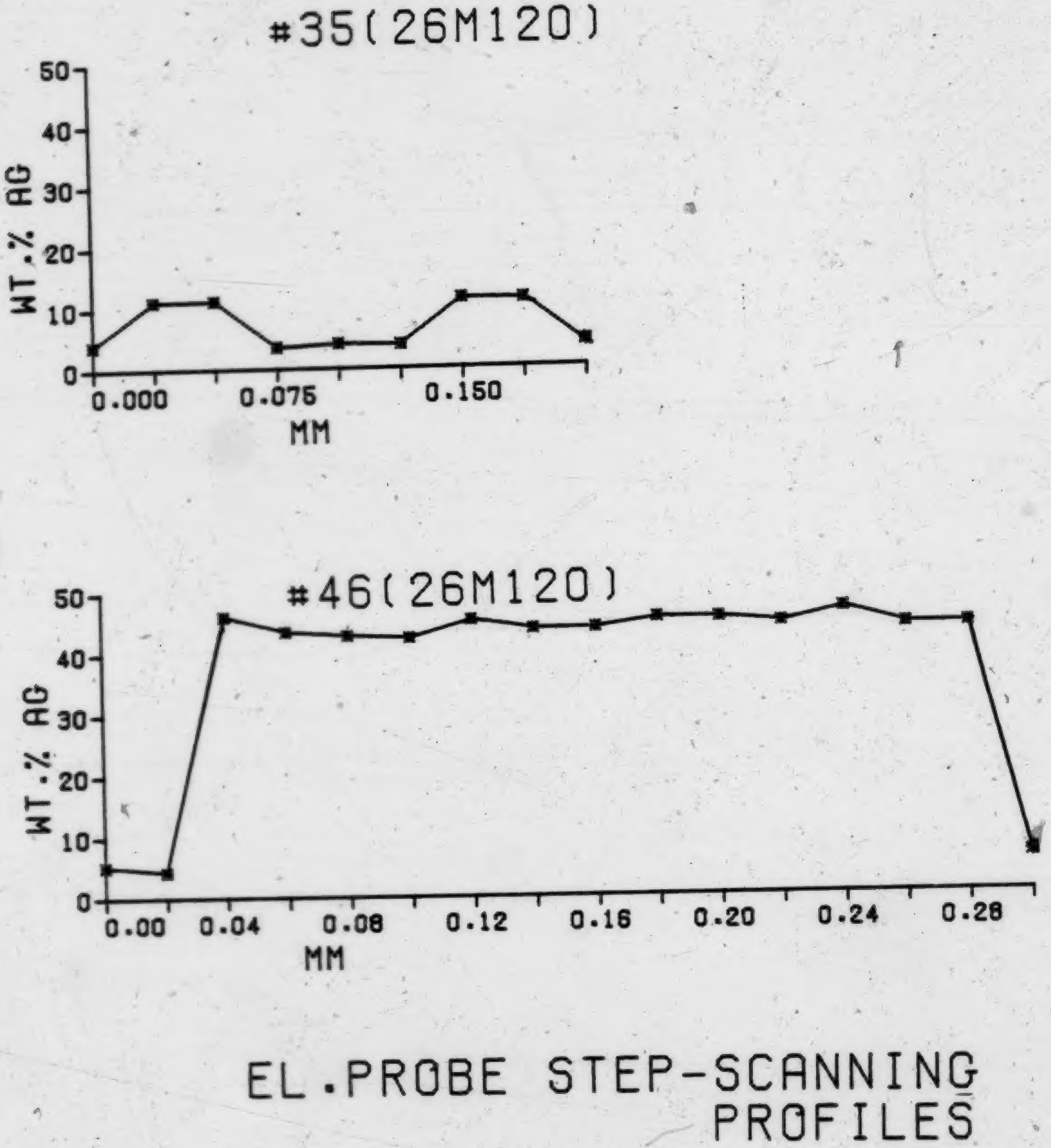
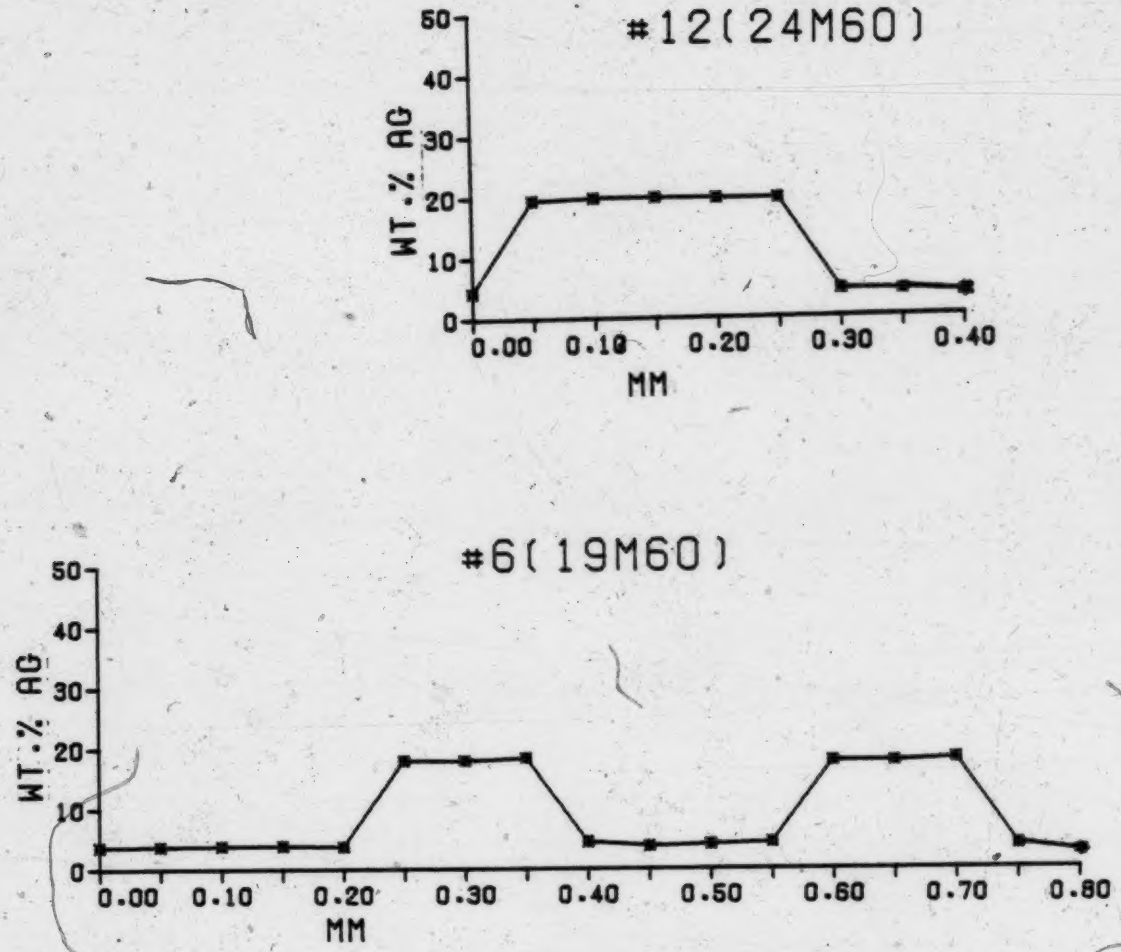
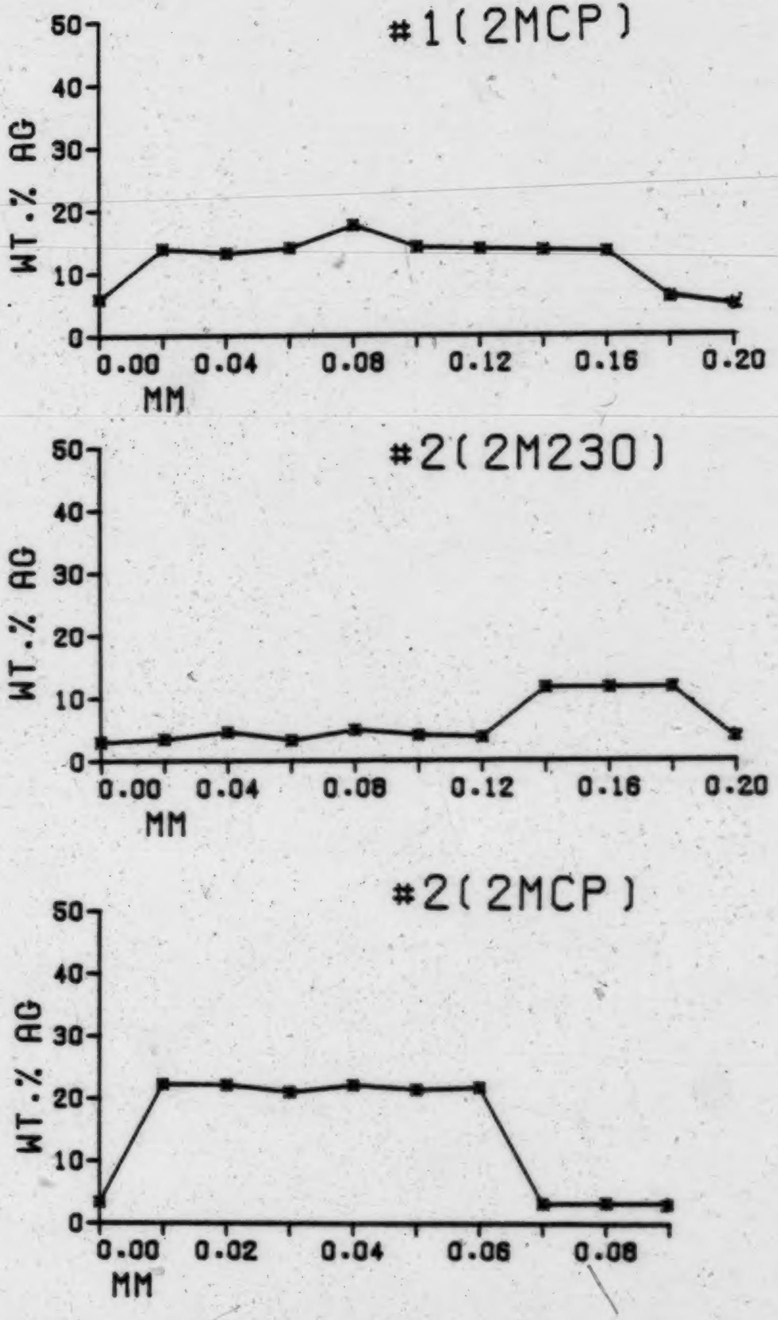

#35(26M120)
WT.% AG
0
10
20
30
40
50
0.000
0.075
0.150
MM
#46(26M120)
WT.% AG
0
10
20
30
40
50
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
MM
EL.PROBE STEP-SCANNING PROFILES

Figure 13



EL.PROBE STEP-SCANNING PROFILES

Figure 14



EL.PROBE STEP-SCANNING PROFILES

Figure 15

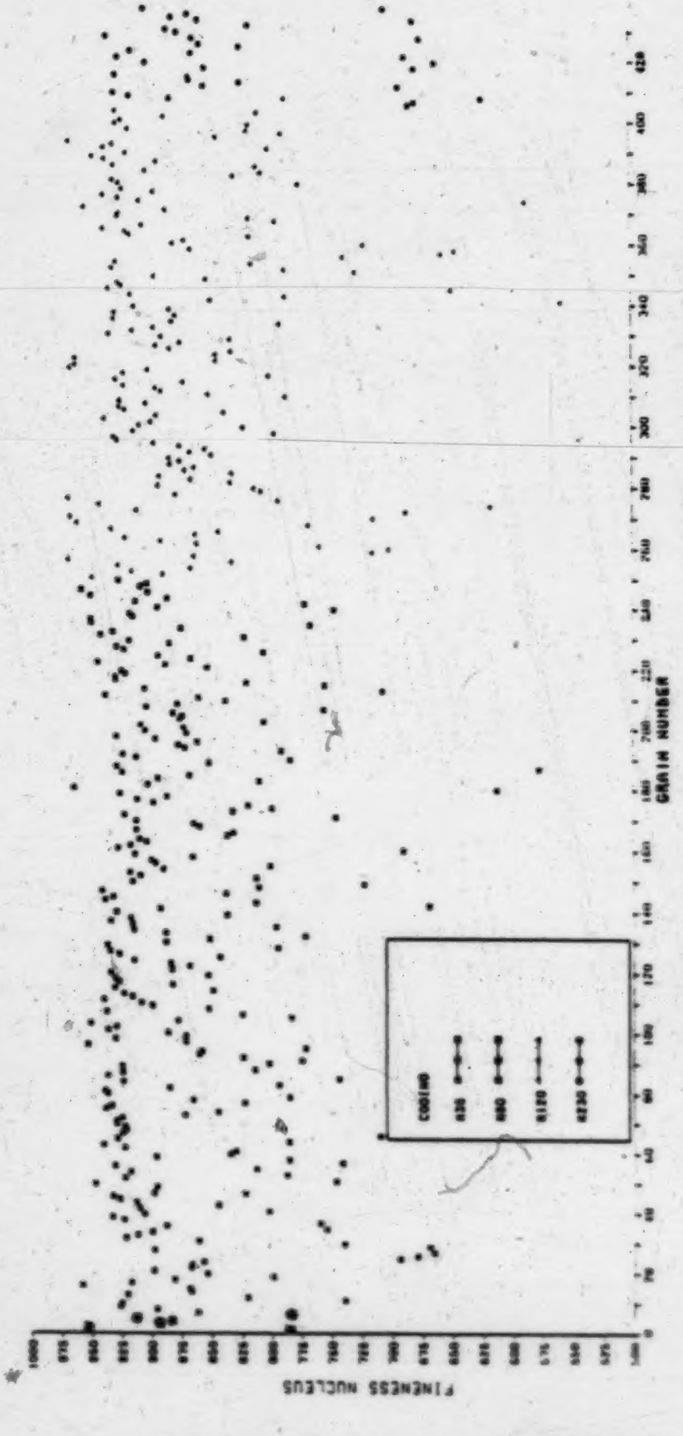


Figure 16: Diagram of the fineness in the nucleus of 440 gold grains from the North Saskatchewan River

N.SASKATCHEWAN R.: FINENESS
IN THE NUCL. OF 440 GOLD GRAINS

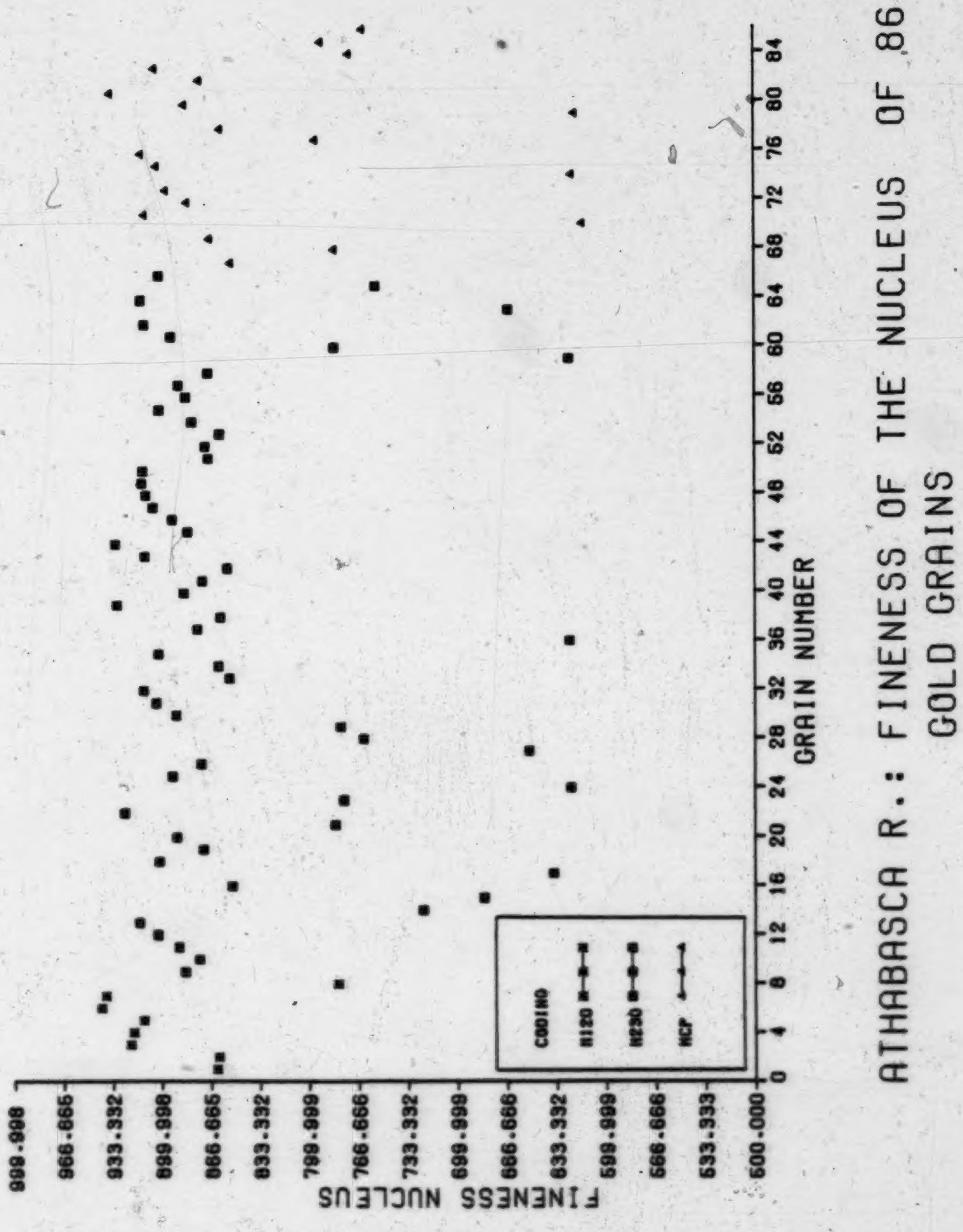


Figure 17: Diagram of the fineness in the nucleus of 86 gold grains from the Athabasca River

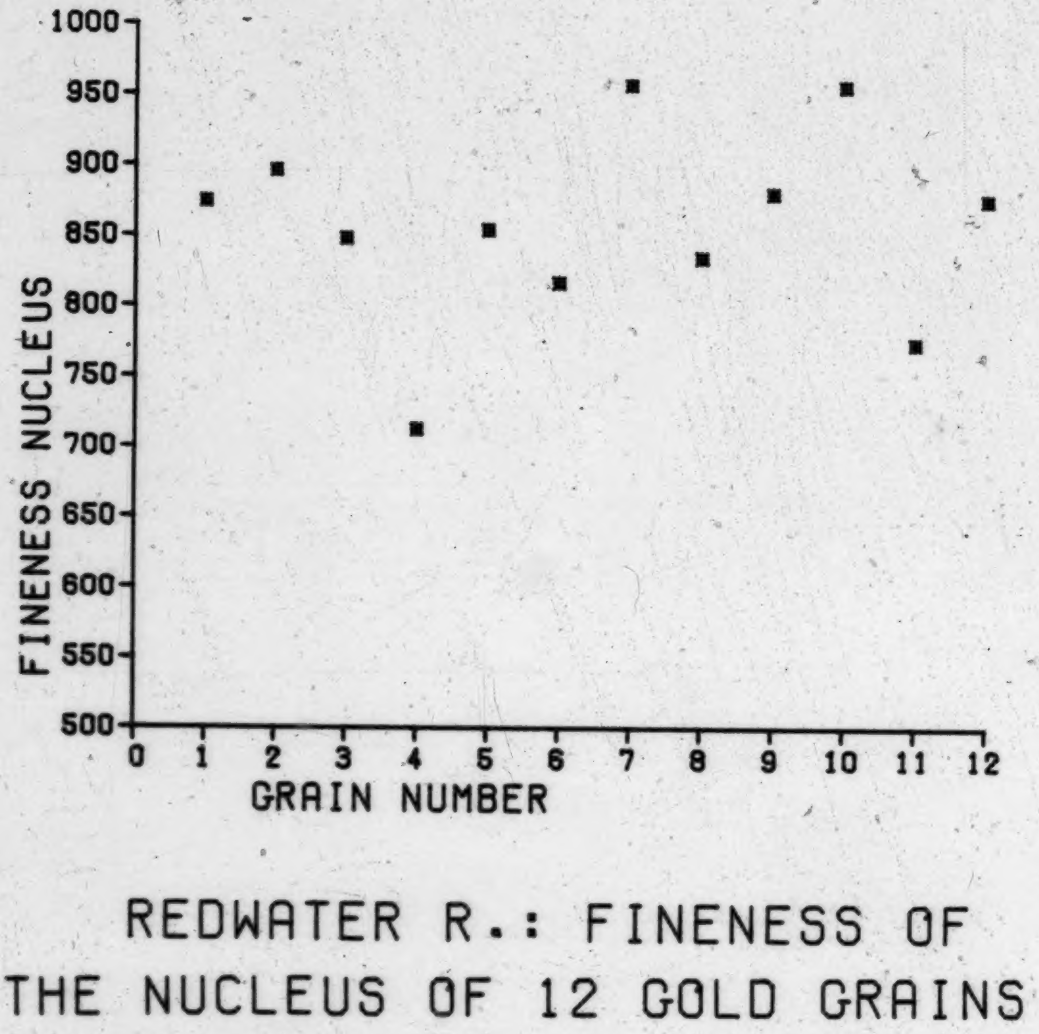
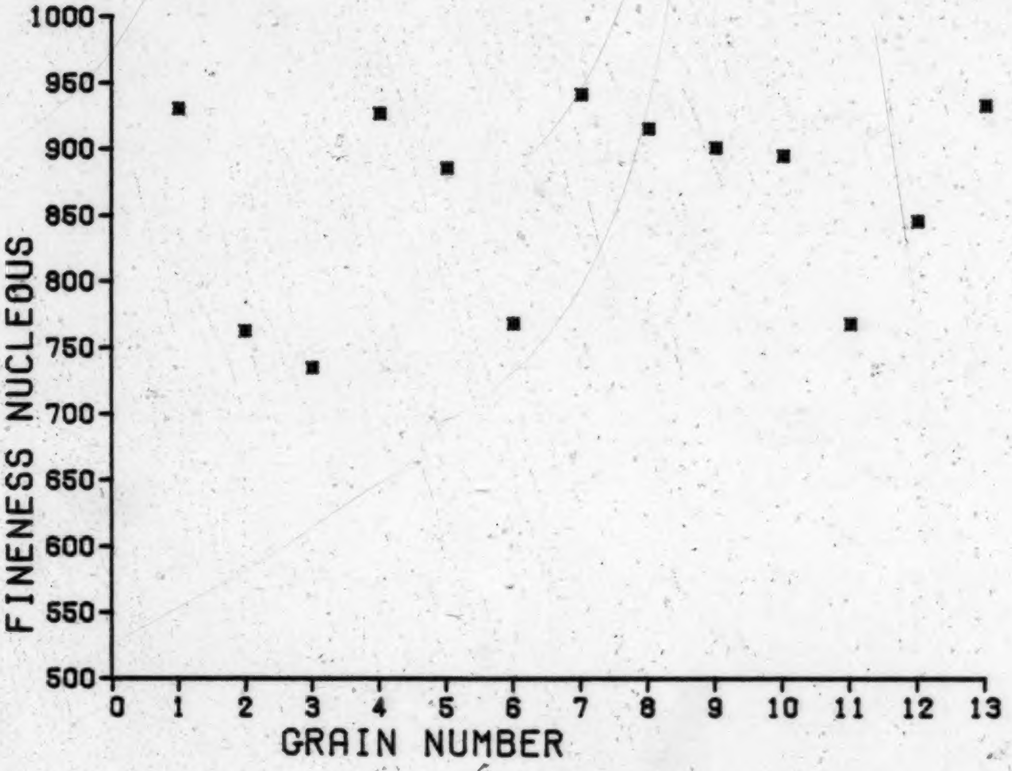


Figure 18: Diagram of the fineness in the nucleus of 12 gold grains from the Redwater River



VERMILION R.: FINENESS OF THE NUCLEUS OF 13 GOLD GRAINS

Figure 19: Diagram of the fineness in the nucleus of 13 gold grains from the Vermilion River

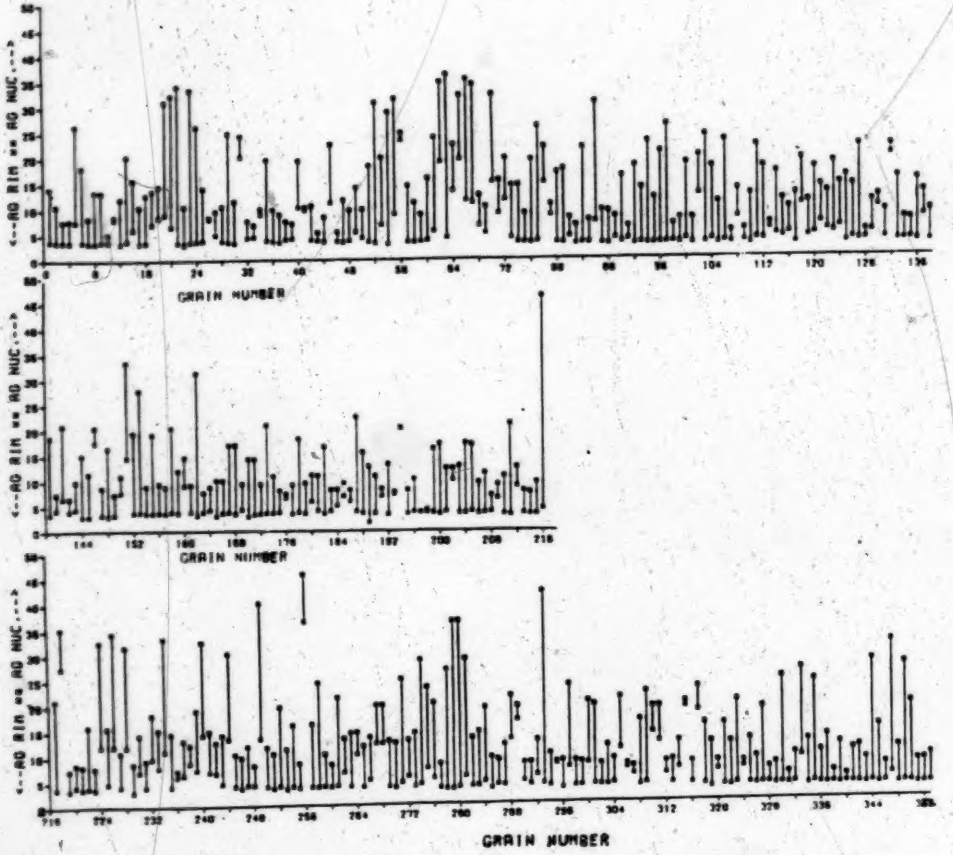


Figure 20: Range in Ag content of 353 gold grains (North Saskatchewan River

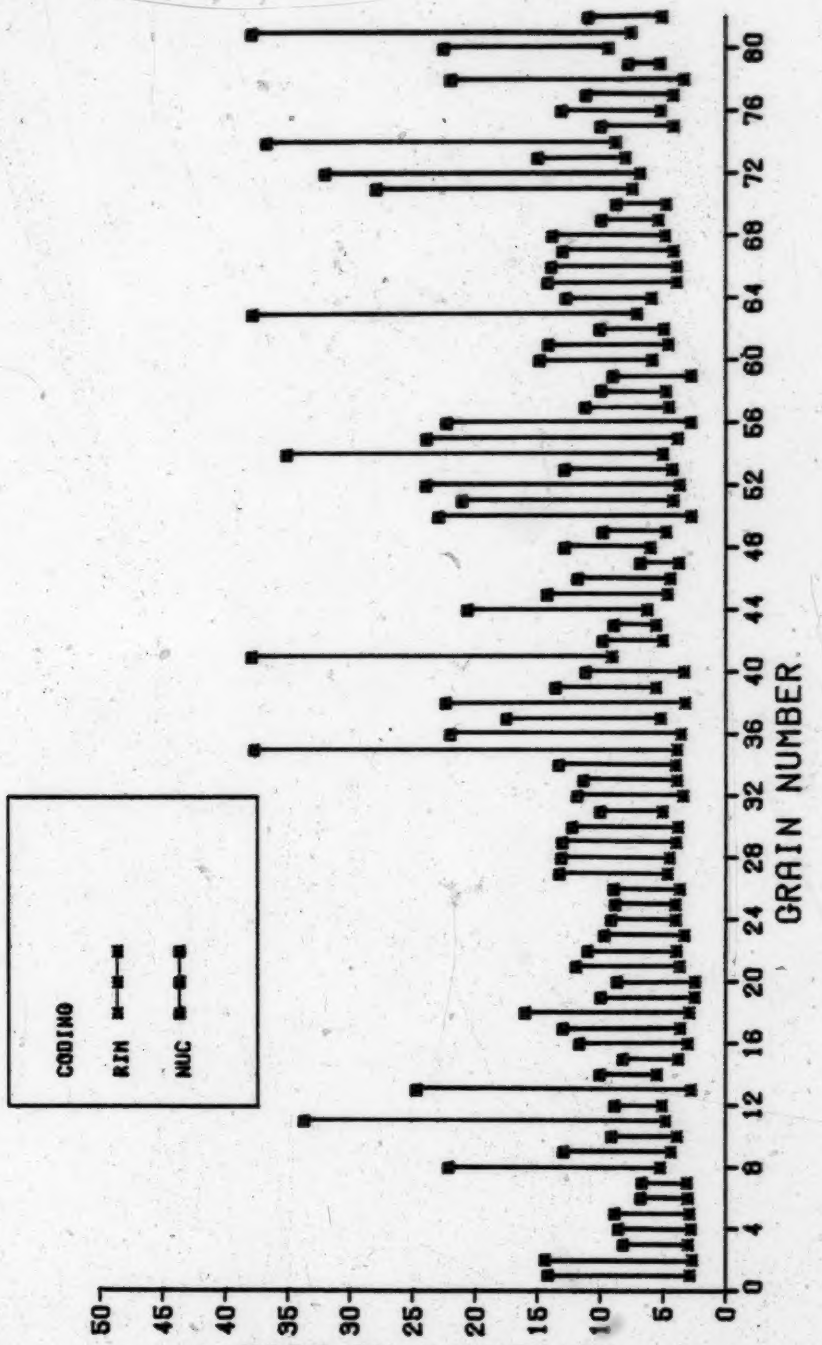
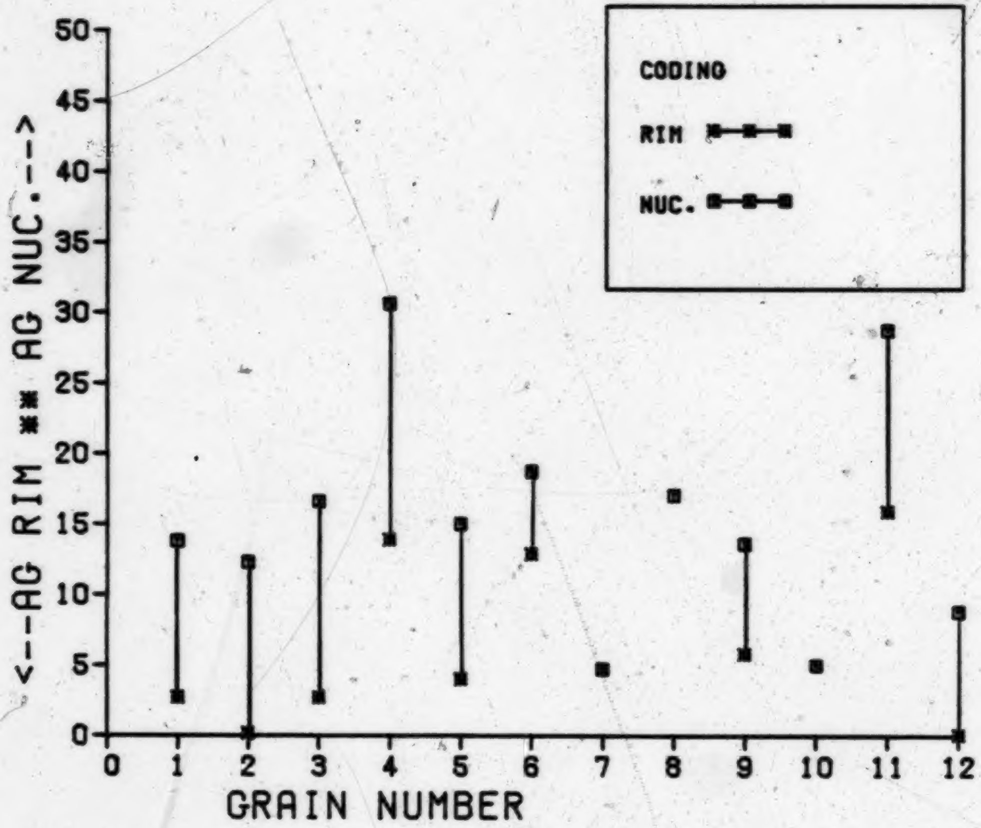
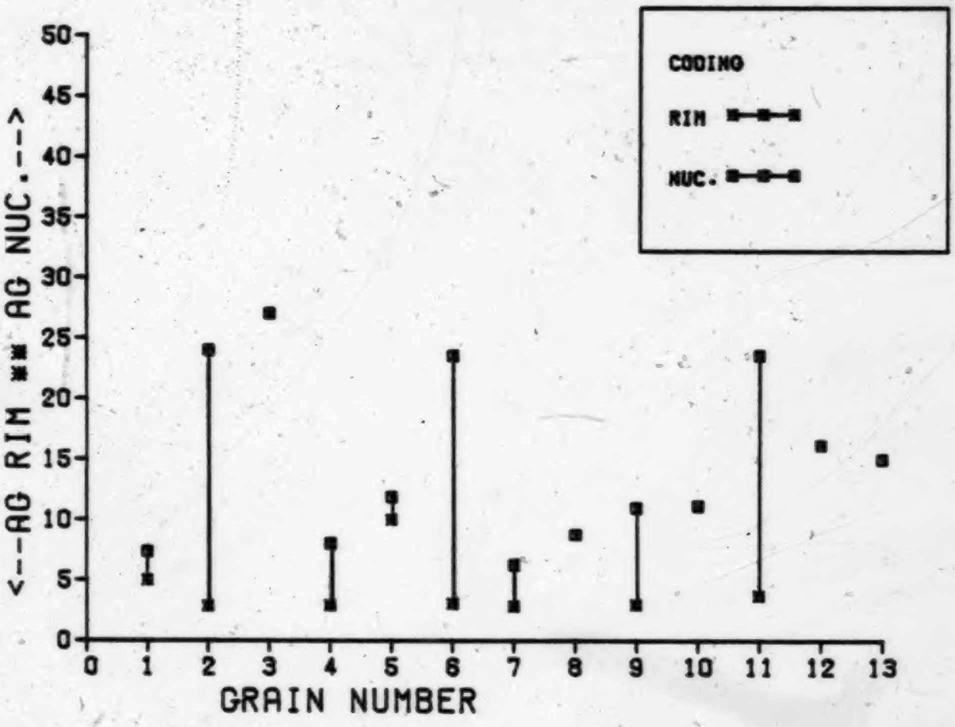


Figure 21: ATHABASCA R.:RANGE IN AG CONTENT OF 82 GOLD GRAINS



REDWATER R.: RANGE IN AG CONTENT OF 12 GOLD GRAINS

Figure 22



VERMILION R.: RANGE IN AG CONTENT OF 13 GOLD GRAINS

Figure 23

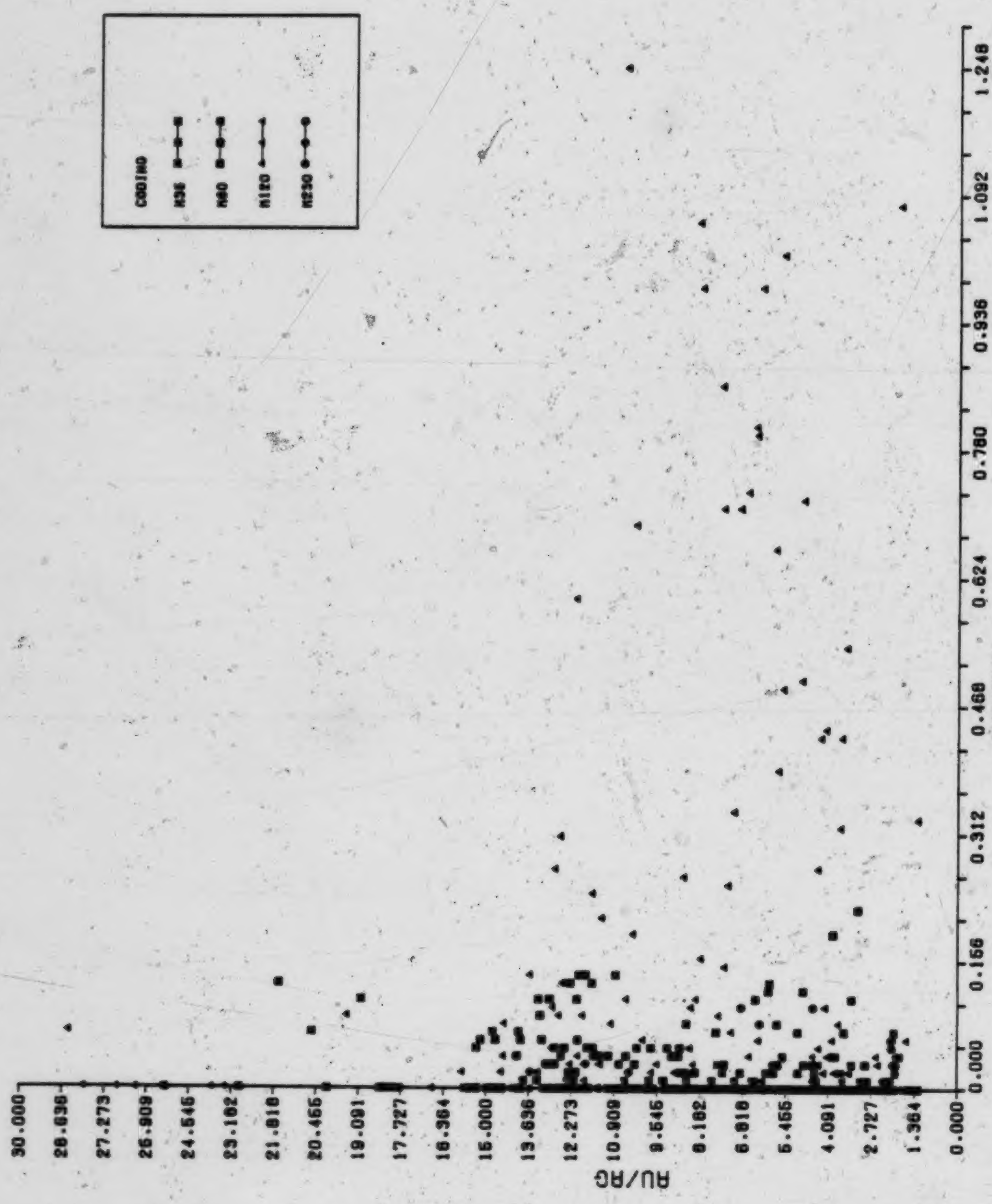
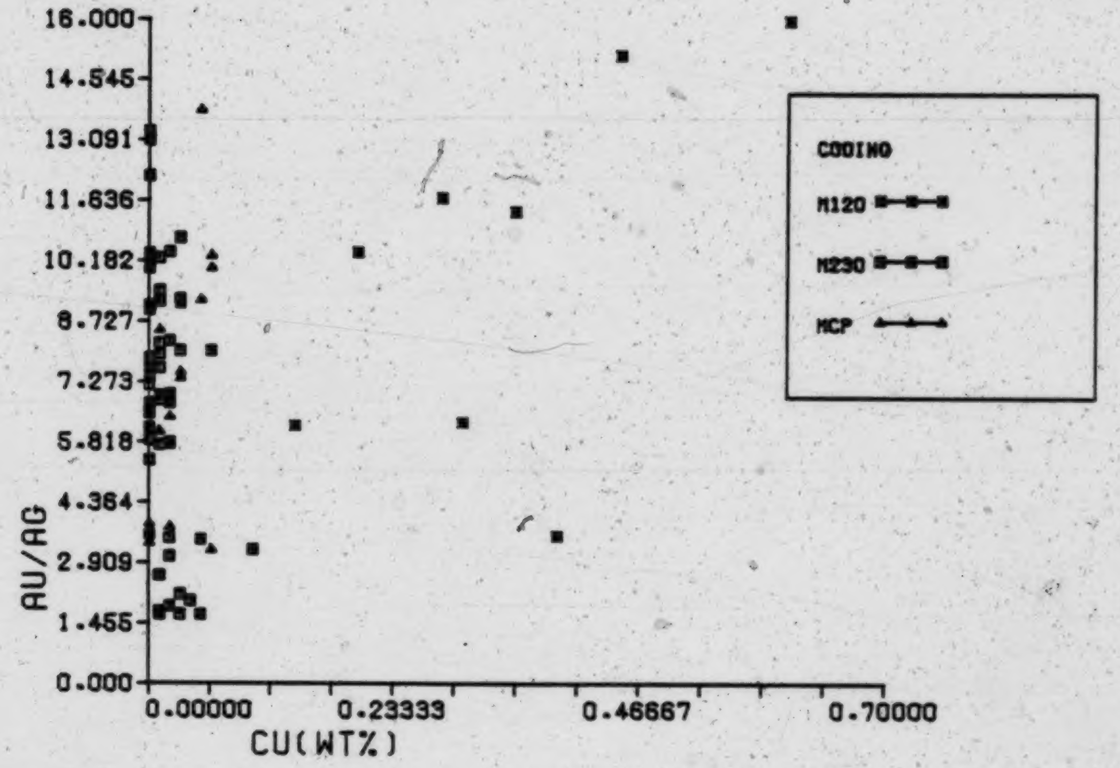
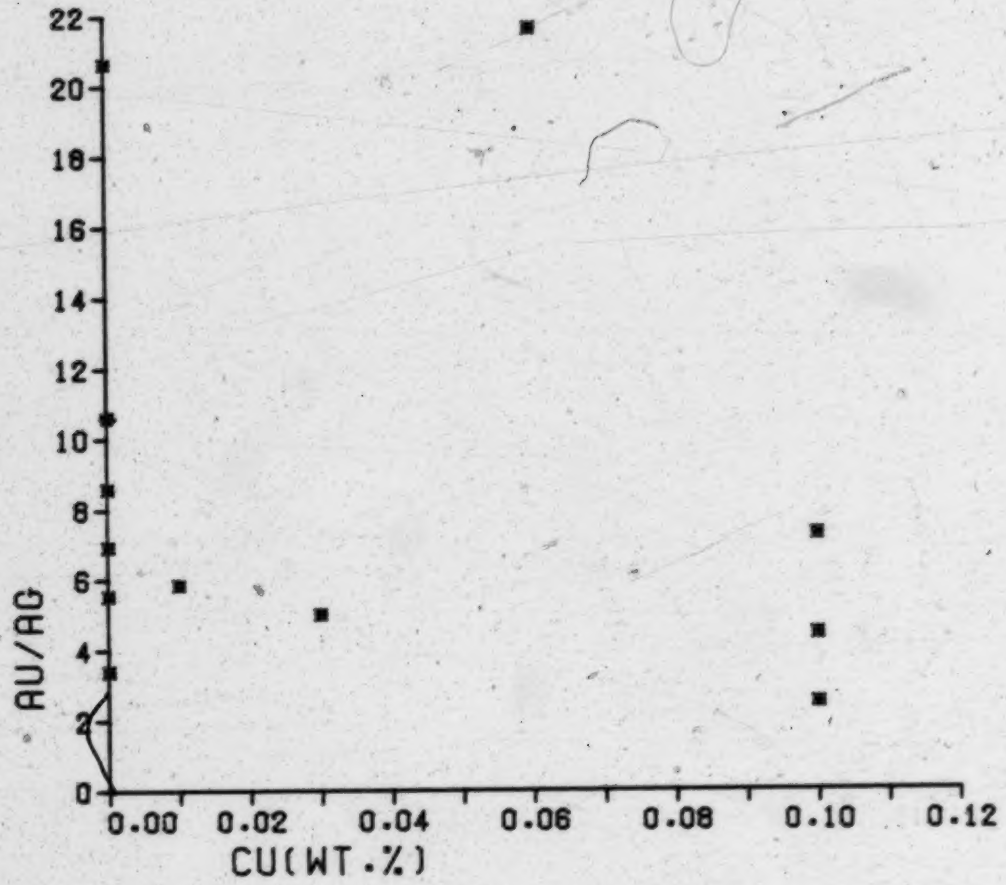


Figure 24. N.SASK.R.: AU/AG AND CU CONT. IN THE NUCL. OF 440 GOLD GR.



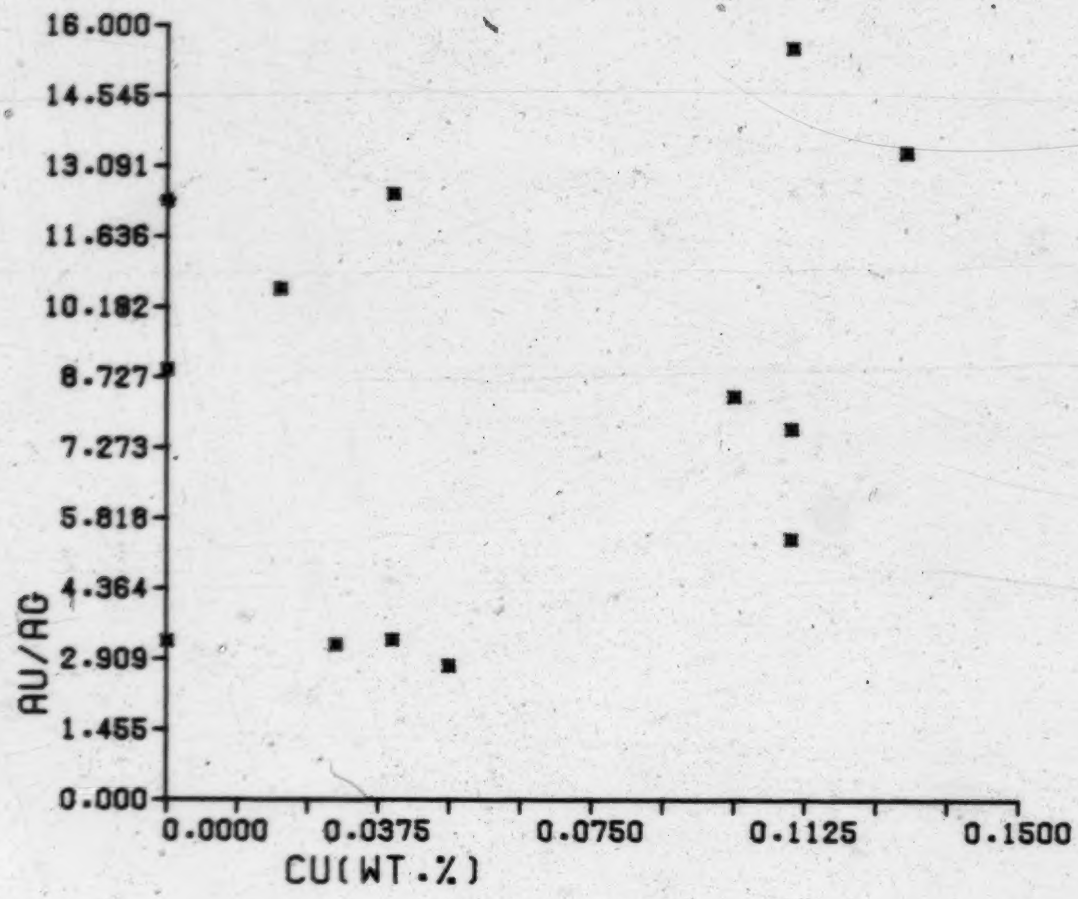
ATHABASCA R.: AU/AG AND CU CONT. IN THE NUCL. OF 86 GOLD GR.

Figure 25



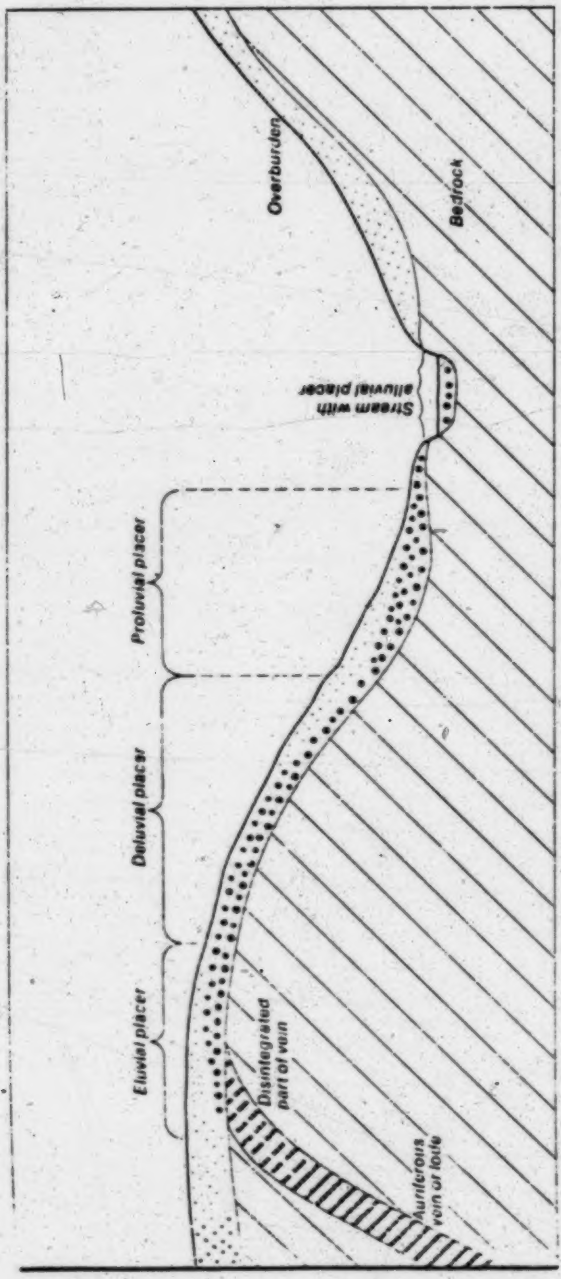
REDWATER R.: AU/AG AND CU
CONT. IN THE NUC. OF 12
GOLD GR.

Figure 26



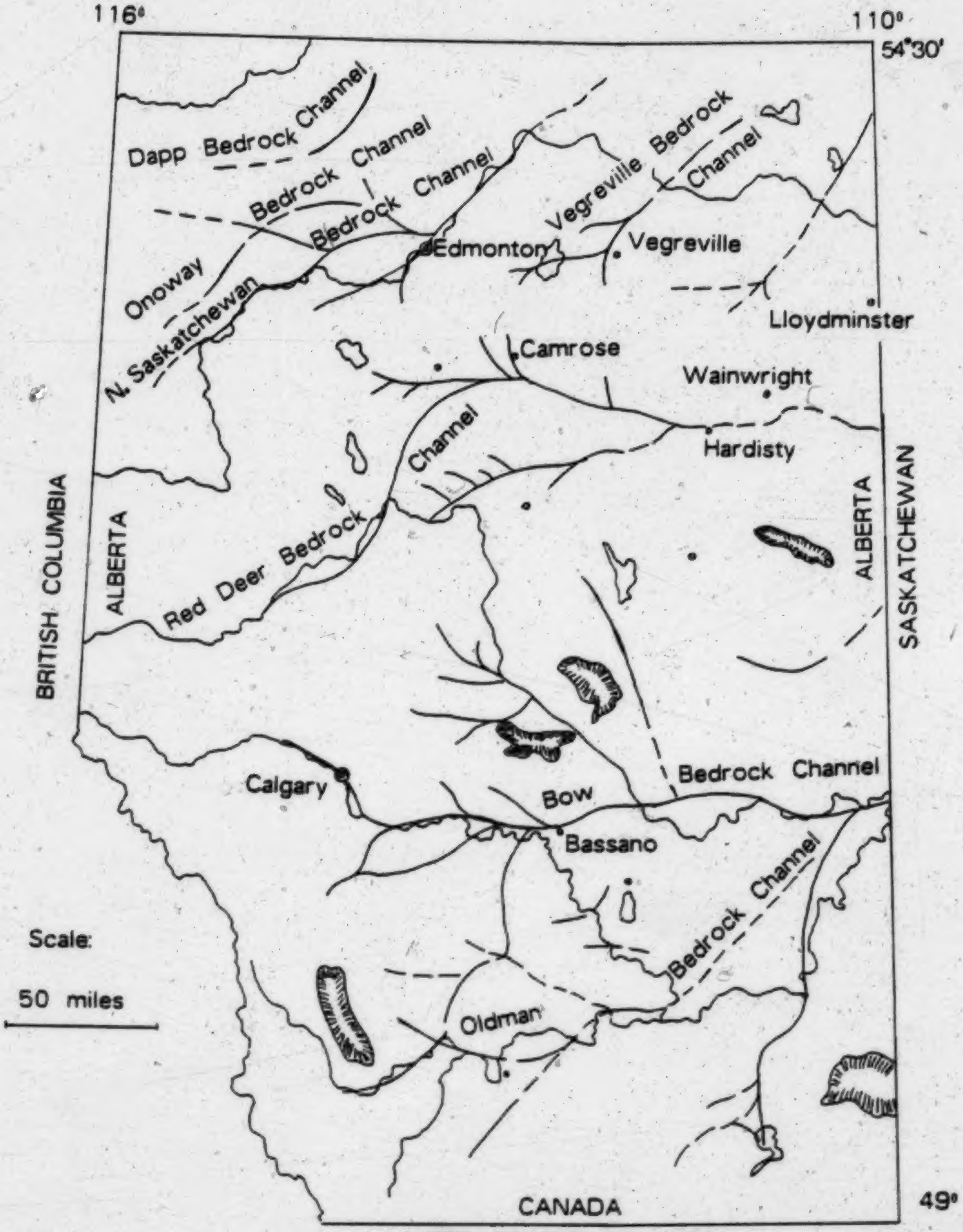
VERMILION R : AU/AG AND CU CONT. IN THE NUC. OF 13 GOLD GR.

Figure 27


Overburden
Bedrock
Stream with alluvial placer
Proluvial placer
Deluvial placer
Eluvial placer
Disintegrated part of vein
Auriferous vein or lode

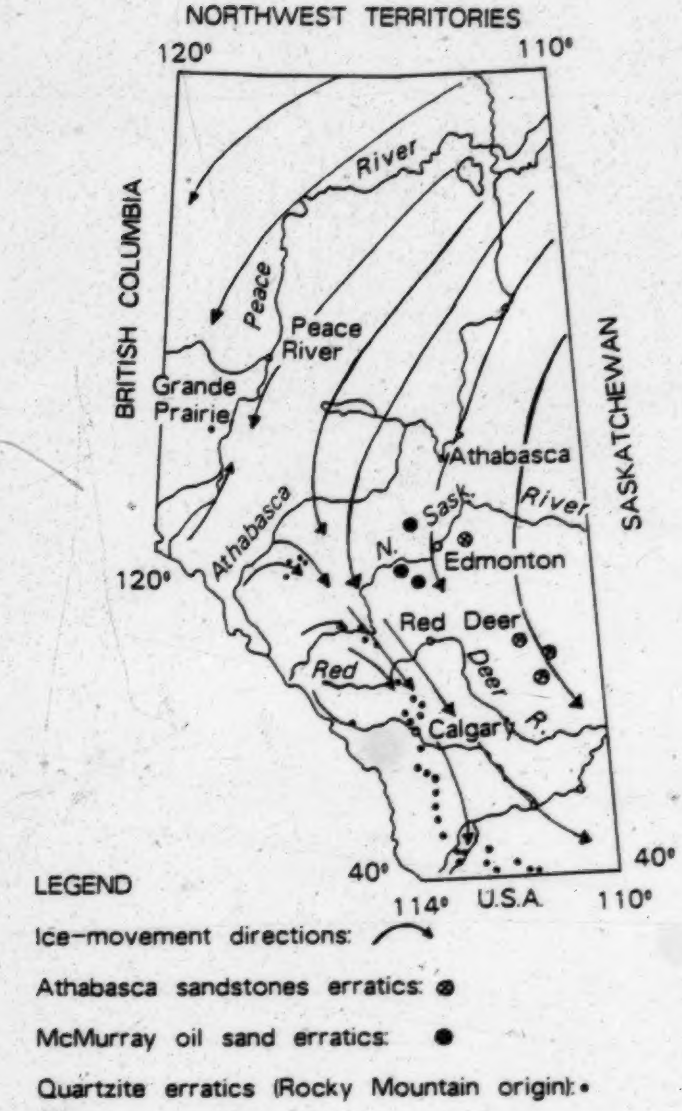
Source: Boyle, 1979

Figure 28: Sketch illustrating eluvial, deluvial and proluvial placers


116°
110°
54°30'
Dapp Bedrock Channel
Bedrock Channel
Bedrock Channel
Onoway
N. Saskatchewan
Bedrock
Vegreville Bedrock
Channel
Edmonton
Vegreville
Lloydminster
Camrose
Wainwright
Hardisty
Channel
Red Deer Bedrock
BRITISH COLUMBIA
ALBERTA
ALBERTA
SASKATCHEWAN
Calgary
Bow
Bedrock Channel
Bassano
Bedrock Channel
Oldman
Scale:
50 miles
CANADA
49°
114°
UNITED STATES OF AMERICA
110°

Source: Gravenor and Bayrock, 1961

Figure 29: Bedrock channels of Southern Alberta


NORTHWEST TERRITORIES
120°
110°
BRITISH COLUMBIA
SASKATCHEWAN
River
Peace
Peace River
Grande Prairie
Athabasca
Athabasca
N. Sask. River
Edmonton
120°
Red Deer
Red
Deer R.
Calgary
40°
40°
114°
U.S.A.
110°
LEGEND
Ice-movement directions:
Athabasca sandstones erratics: ⊗
McMurray oil sand erratics: ●
Quartzite erratics (Rocky Mountain origin): •

Source: Gravenor and Bayrock, 1961.

Figure 30: Generalized ice-advance directions in Alberta

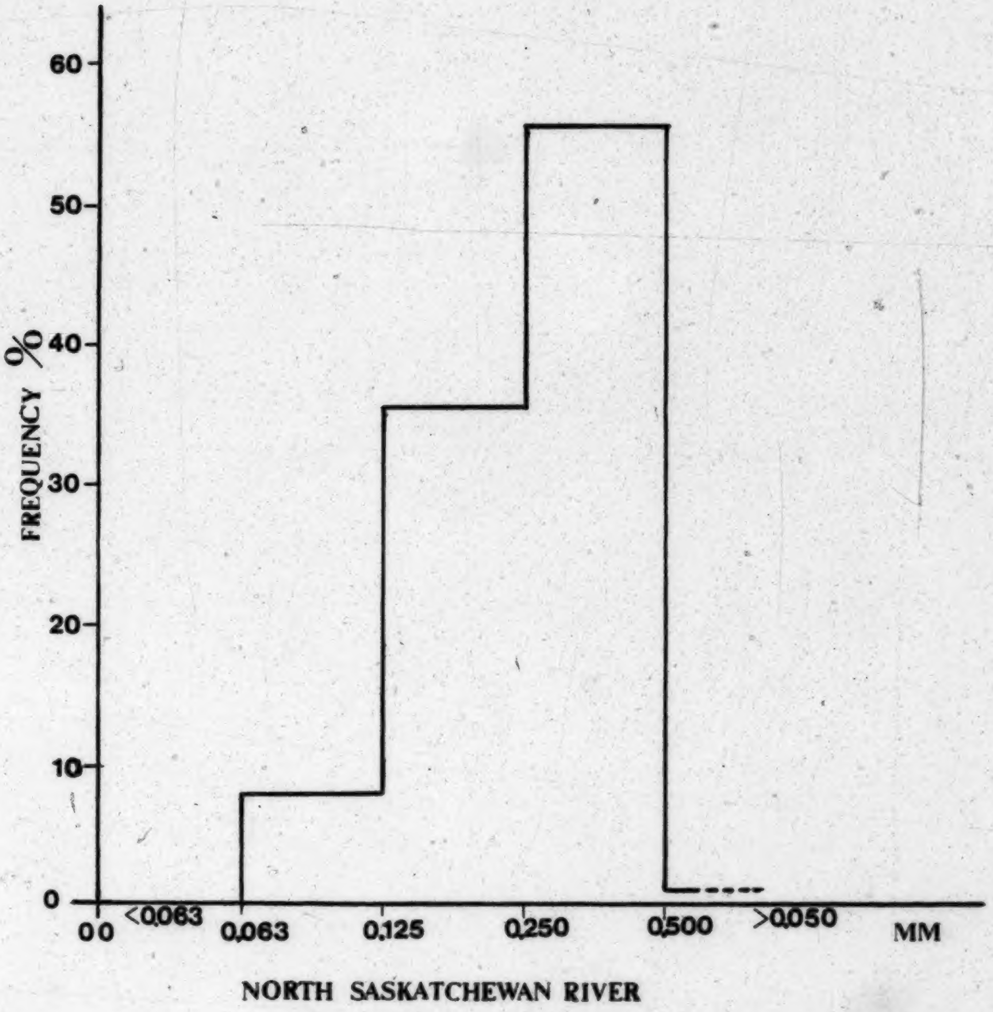


Figure 31: Size distribution of the gold grains from the North Saskatchewan River

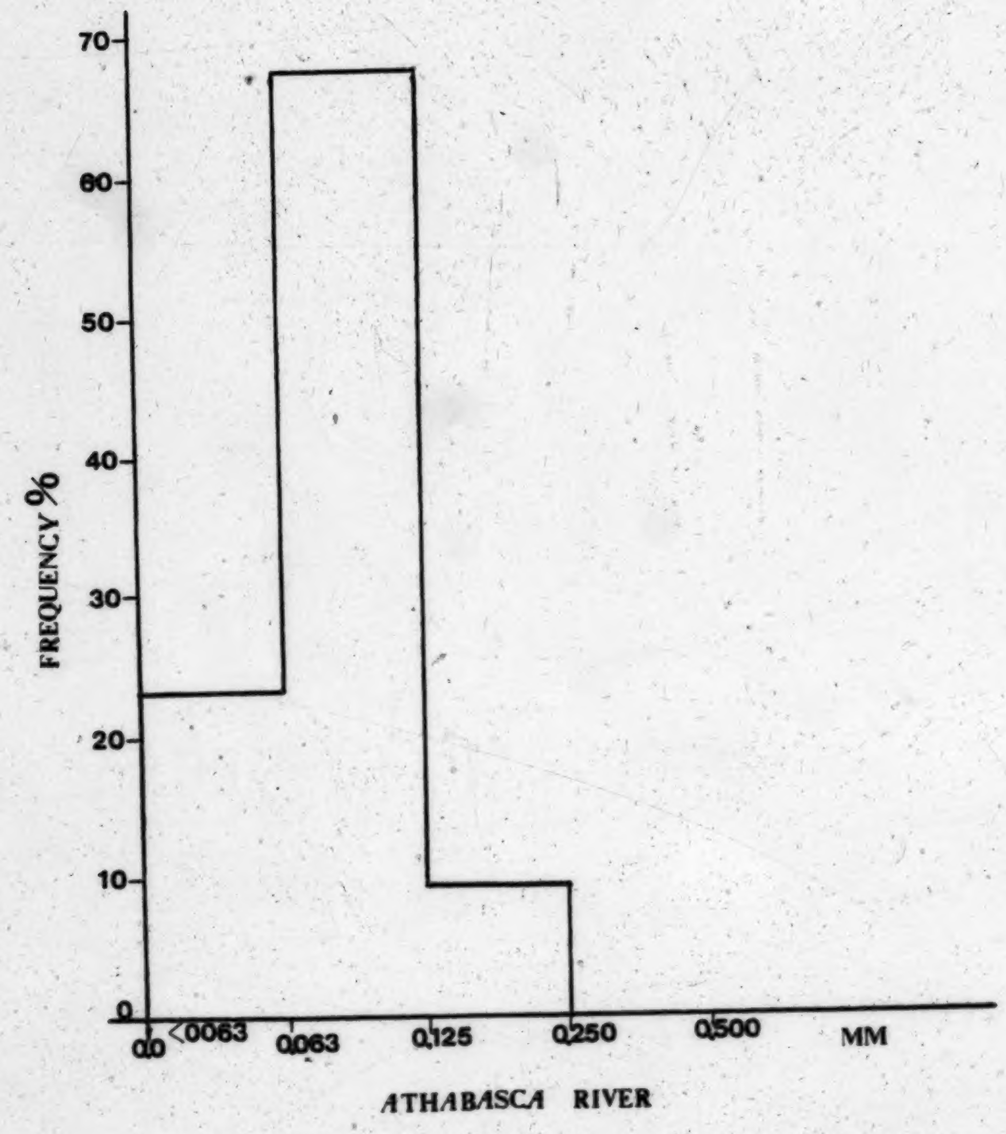


Figure 32: Size distribution of the gold grains from the Athabasca River

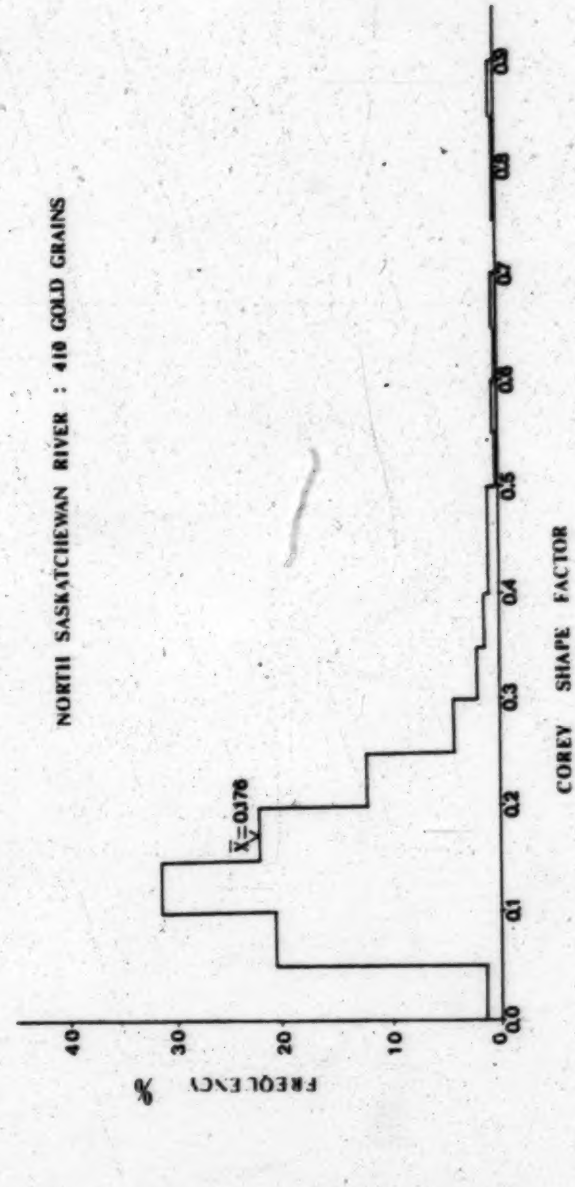


Figure 33: Frequency distribution of the Corey shape factors of 410 gold grains (North Saskatchewan River)

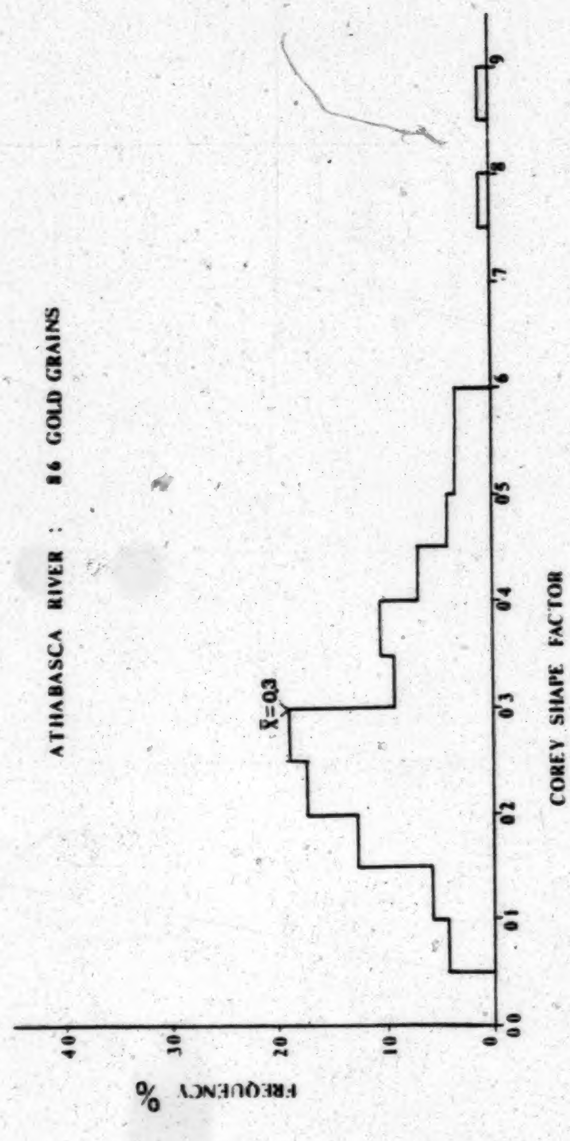


Figure 34: Frequency distribution of the Corey shape factor of 86 gold grains (Athabasca River)

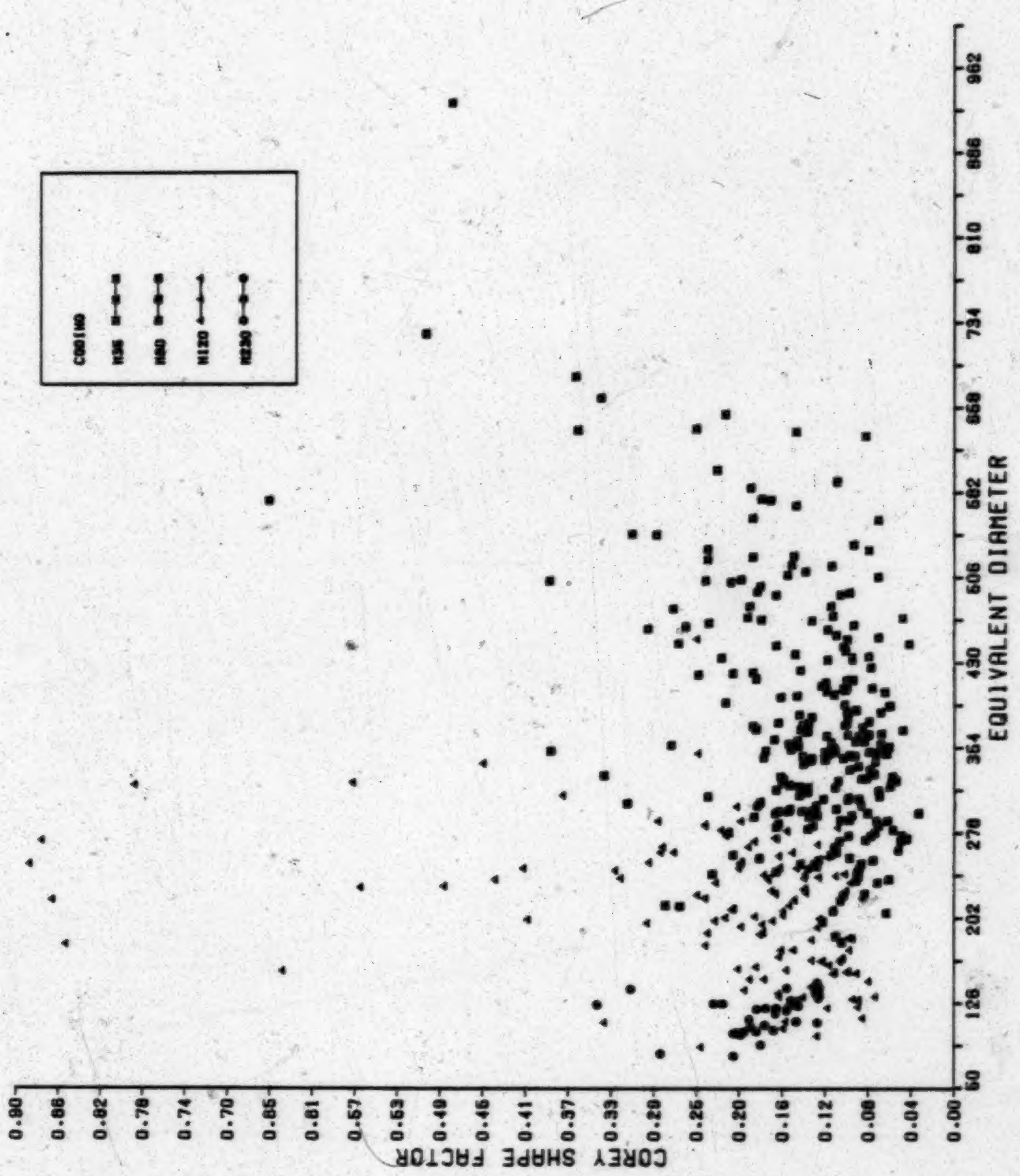


Figure 35. N. SASKATCHEWAN R.: EQ.DIAM./SH.FACTOR OF 410 GOLD GRAINS

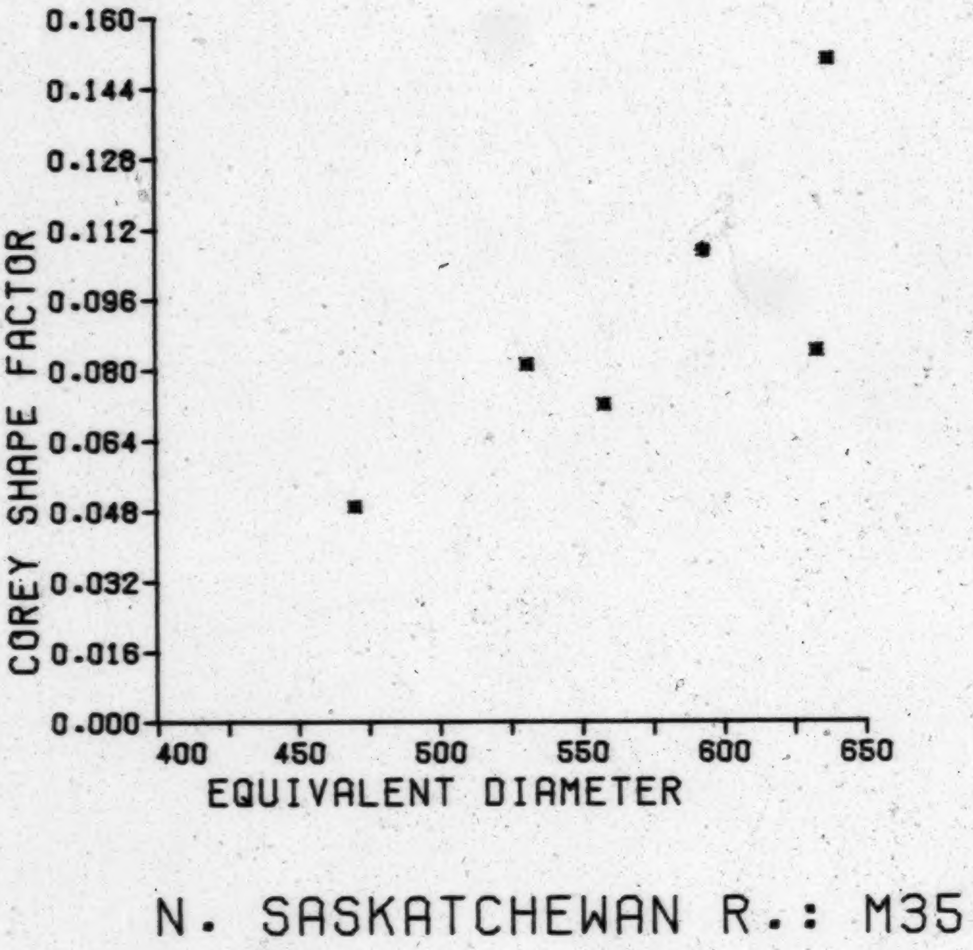


Figure 36: Equivalent diameter versus shape factor; mesh+35. North Saskatchewan River

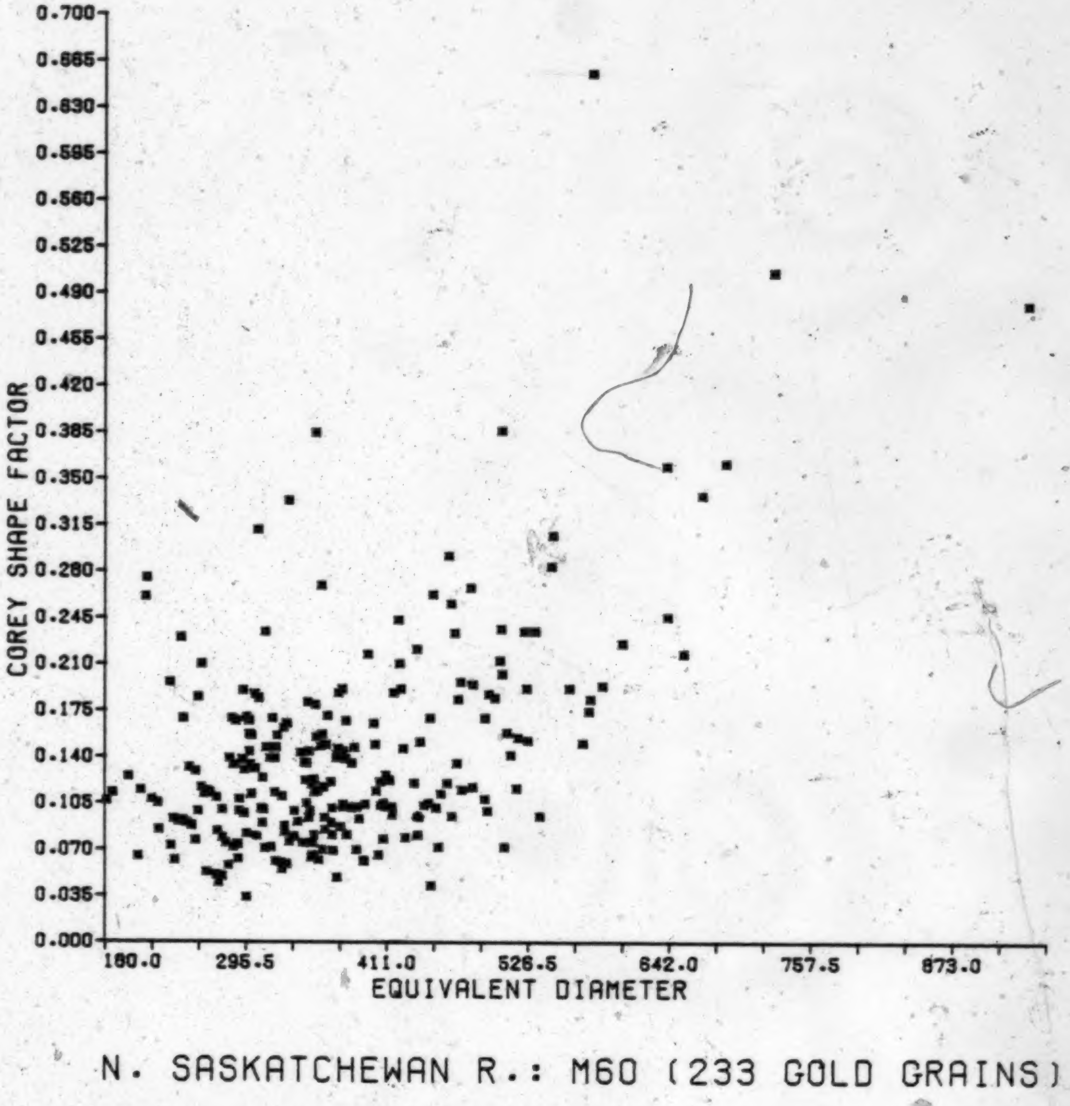


Figure 37: Equivalent diameter versus shape factor; mesh+60. North Saskatchewan River

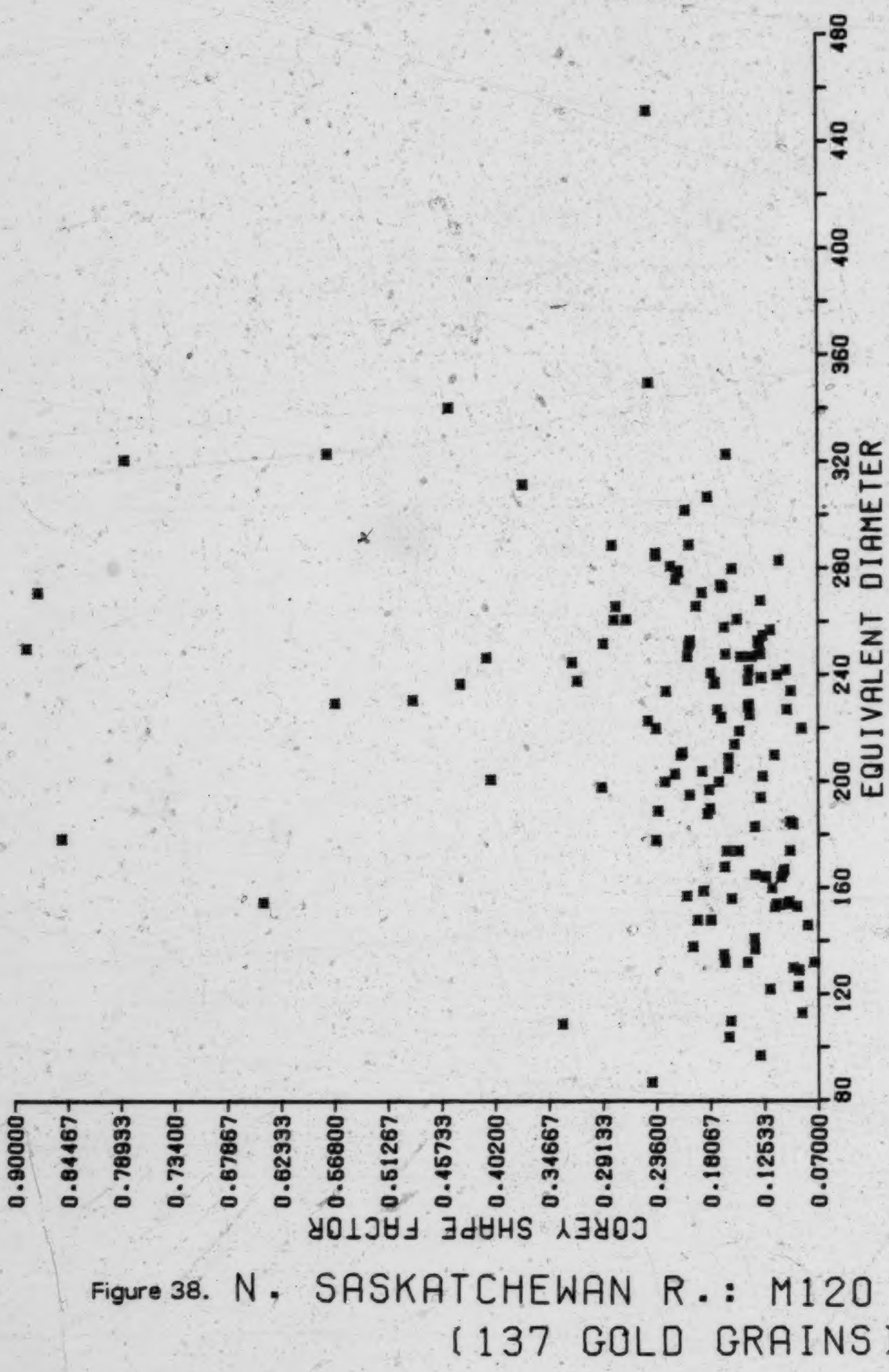


Figure 38. N. SASKATCHEWAN R.: M120
(137 GOLD GRAINS)

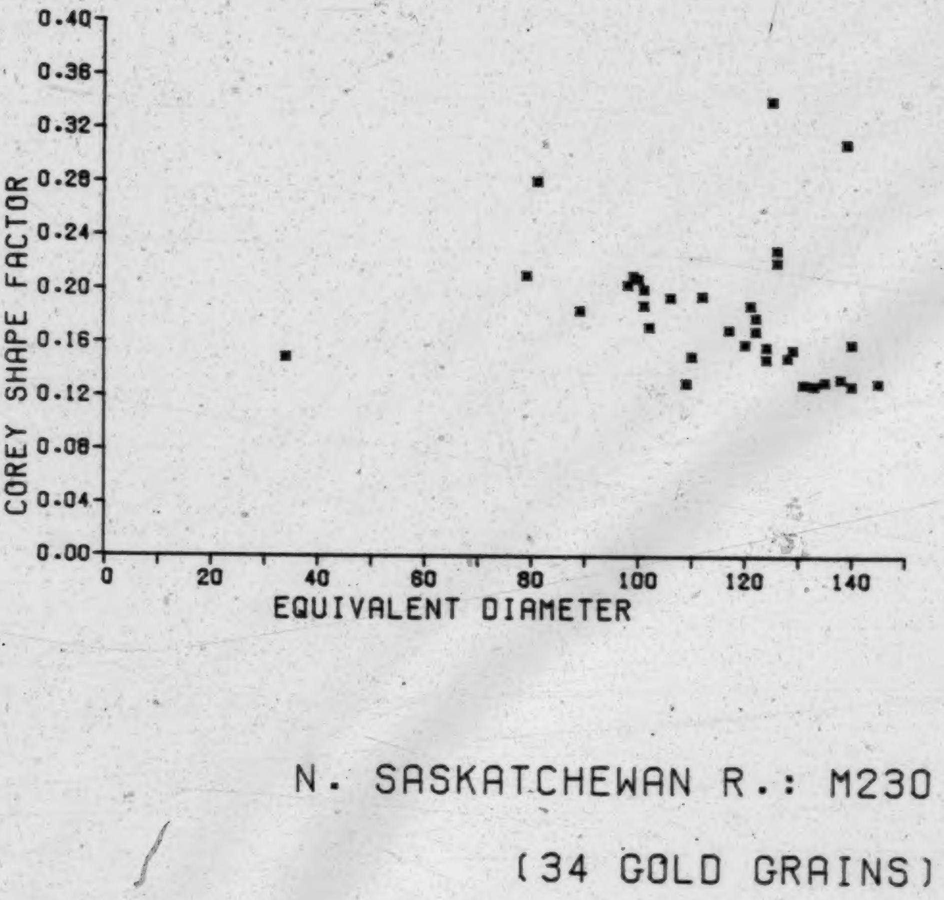


Figure 39: Equivalent diameter versus shape factor; mesh+230. North Saskatchewan River

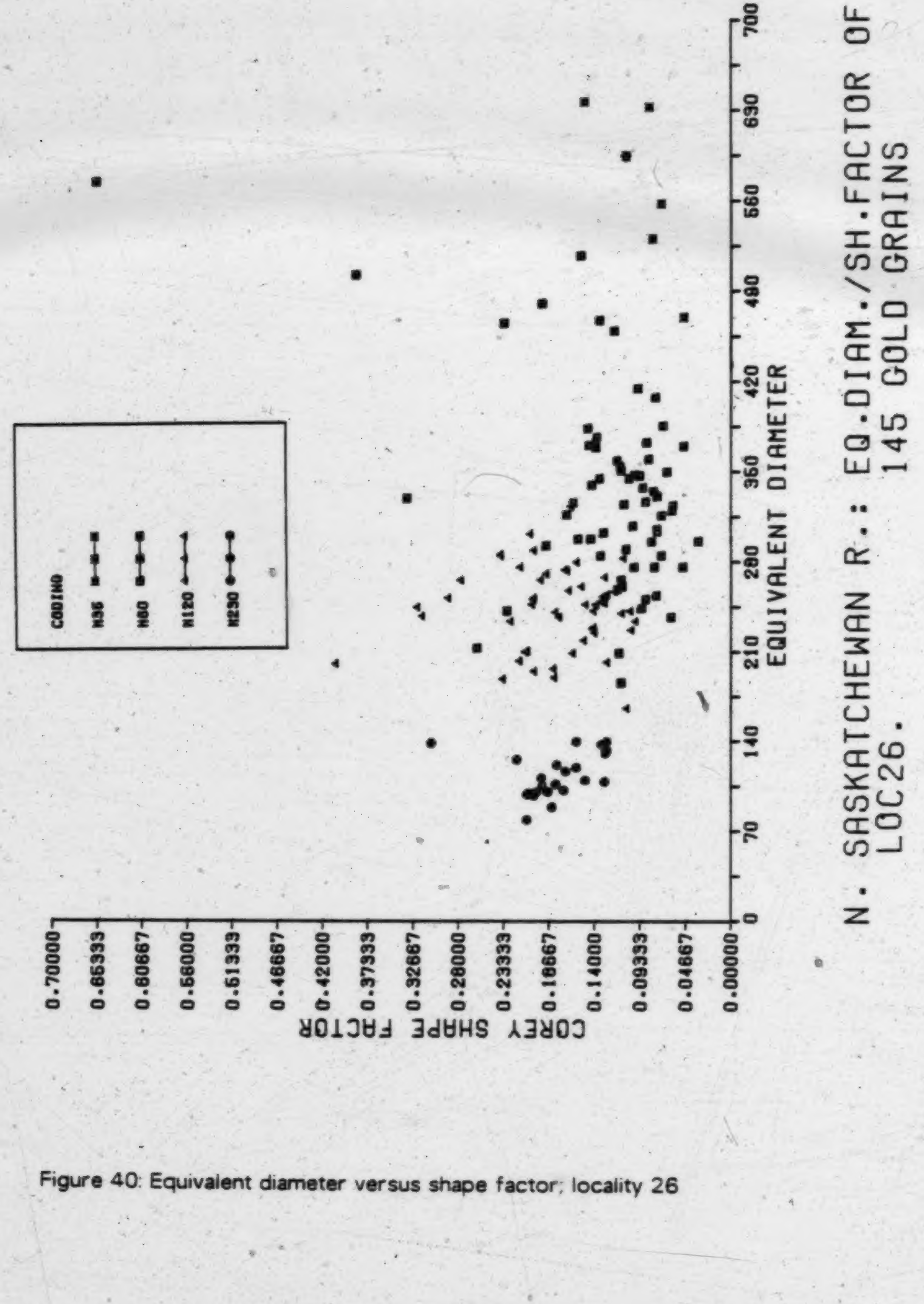


Figure 40: Equivalent diameter versus shape factor; locality 26

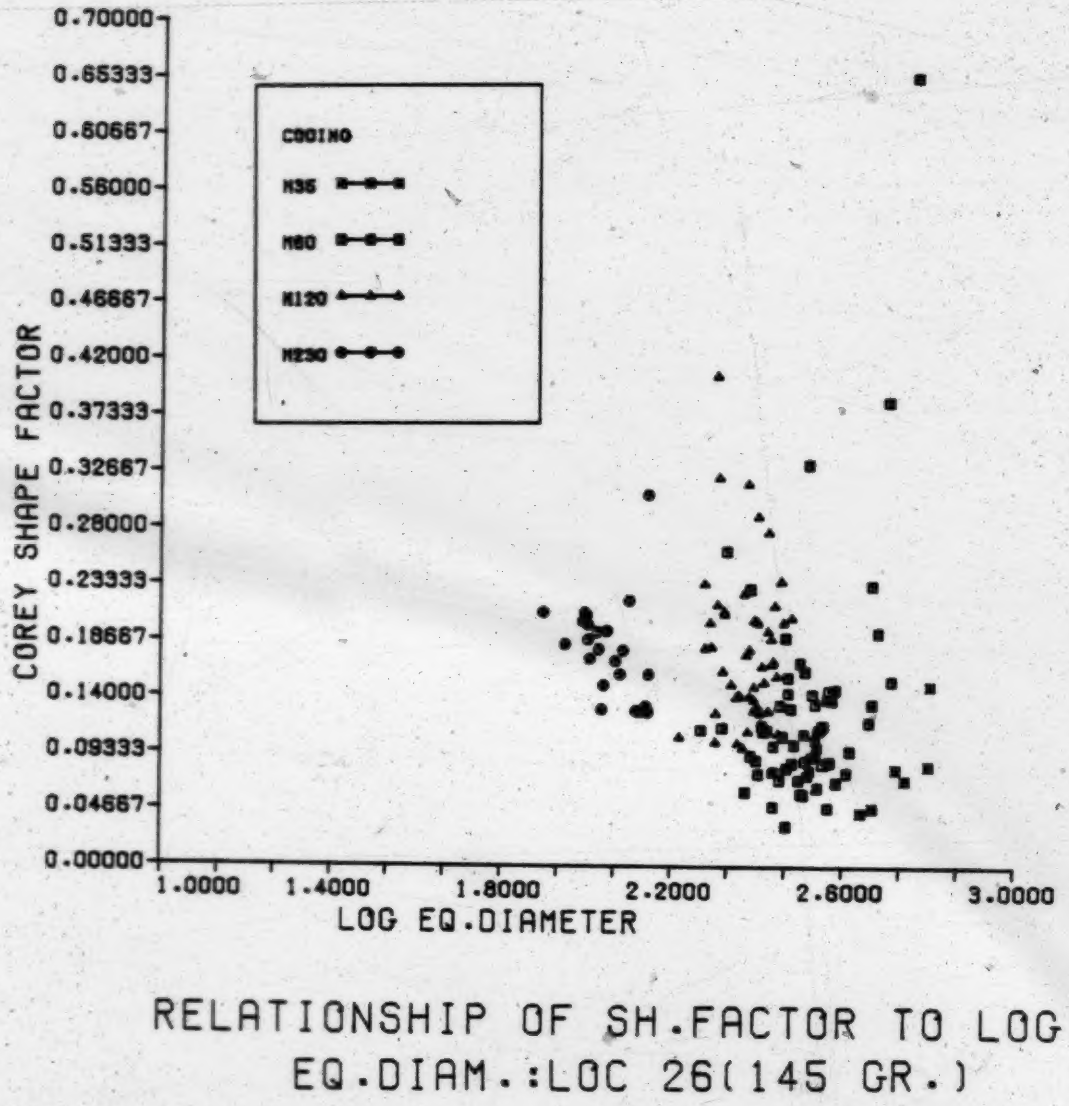
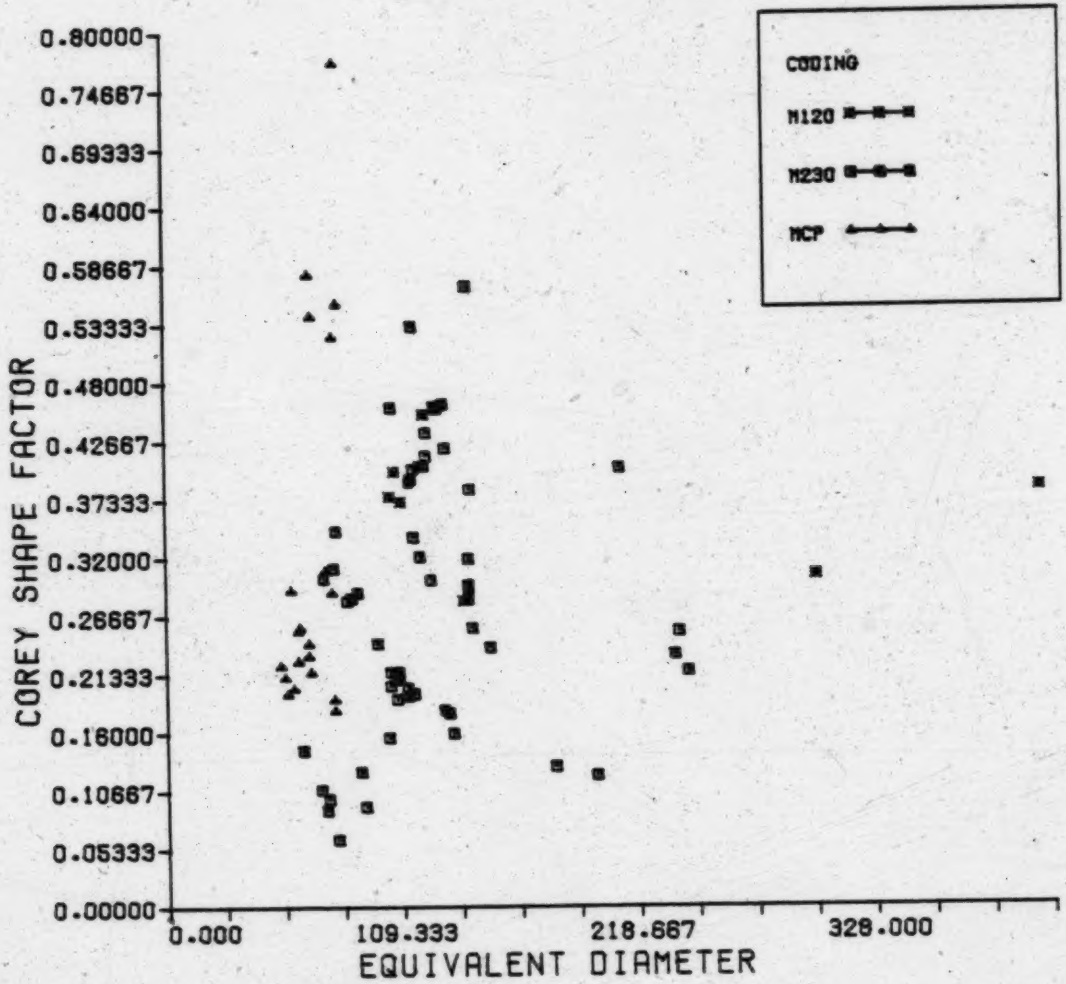


Figure 41: Diagram of shape factor versus log equiv. diam.; locality 26



ATHABASCA R.: EQ.DIAM./SH.FACTOR OF 86 GOLD GRAINS

Figure 42: Diagram of shape factor versus equiv. diam.; Athabasca River

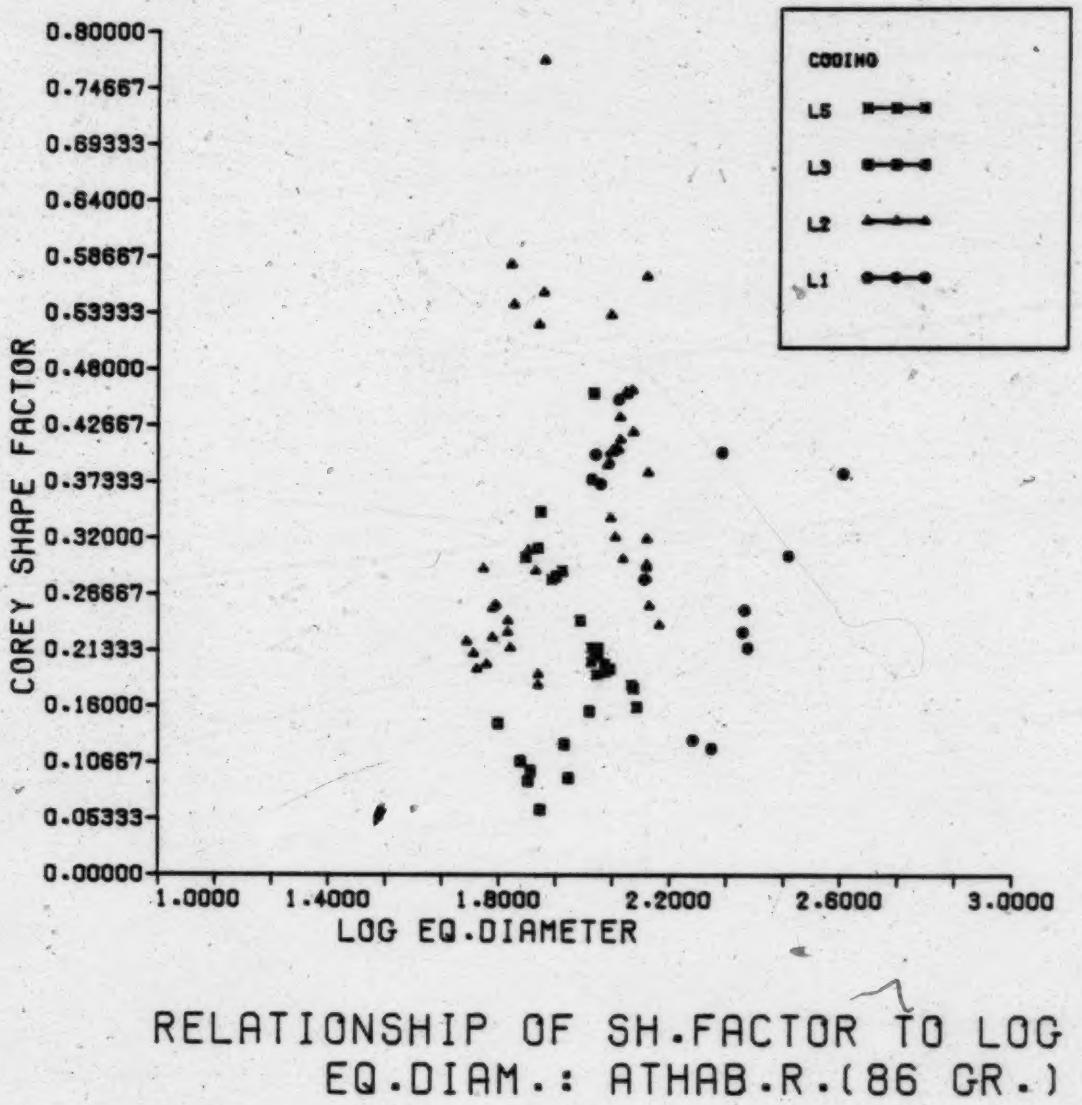
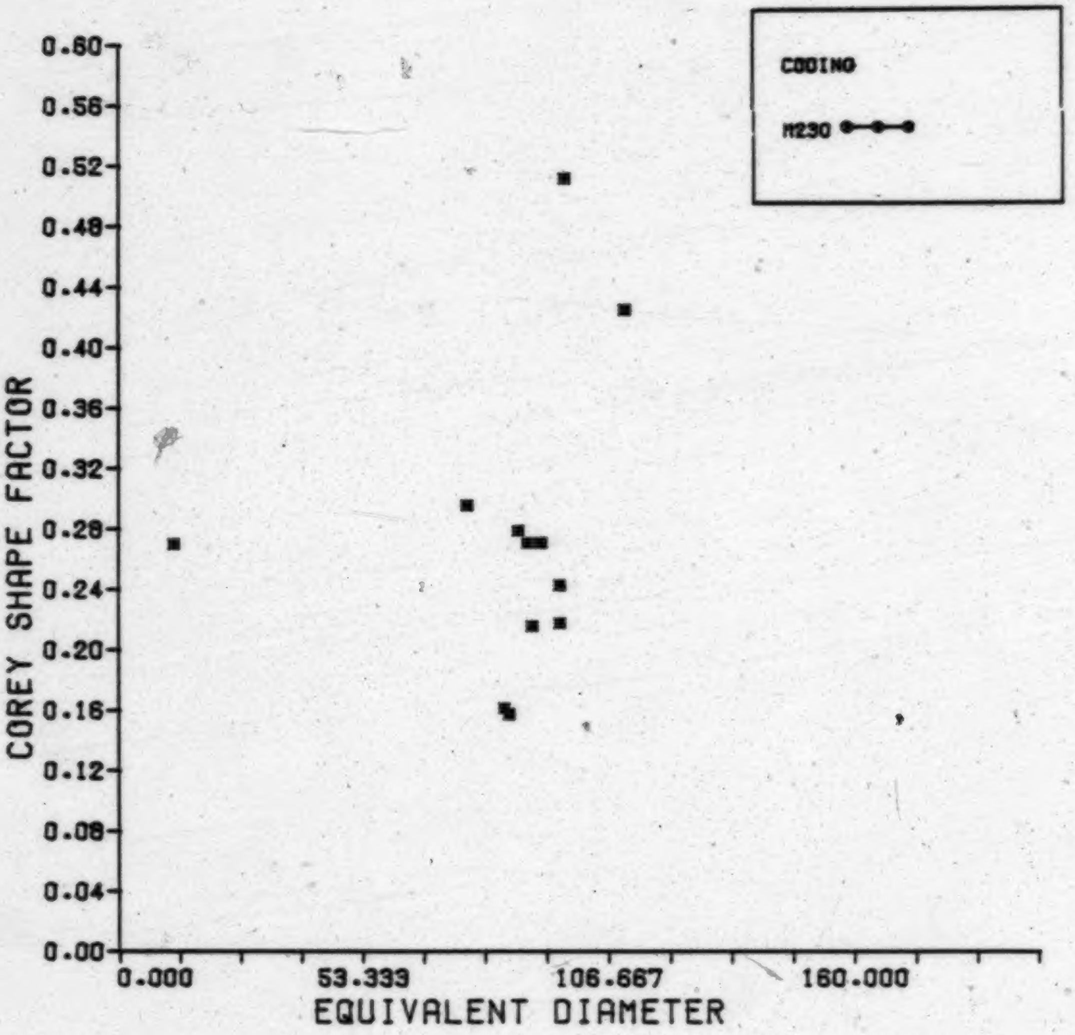


Figure 43: Diagram of shape factor versus log equiv. diam.: Athabasca River



REDWATER R.: EQ.DIAM./SH.FACTOR
OF 12 GOLD GRAINS

Figure 44: Diagram of shape factor versus equiv. diam.; Redwater River

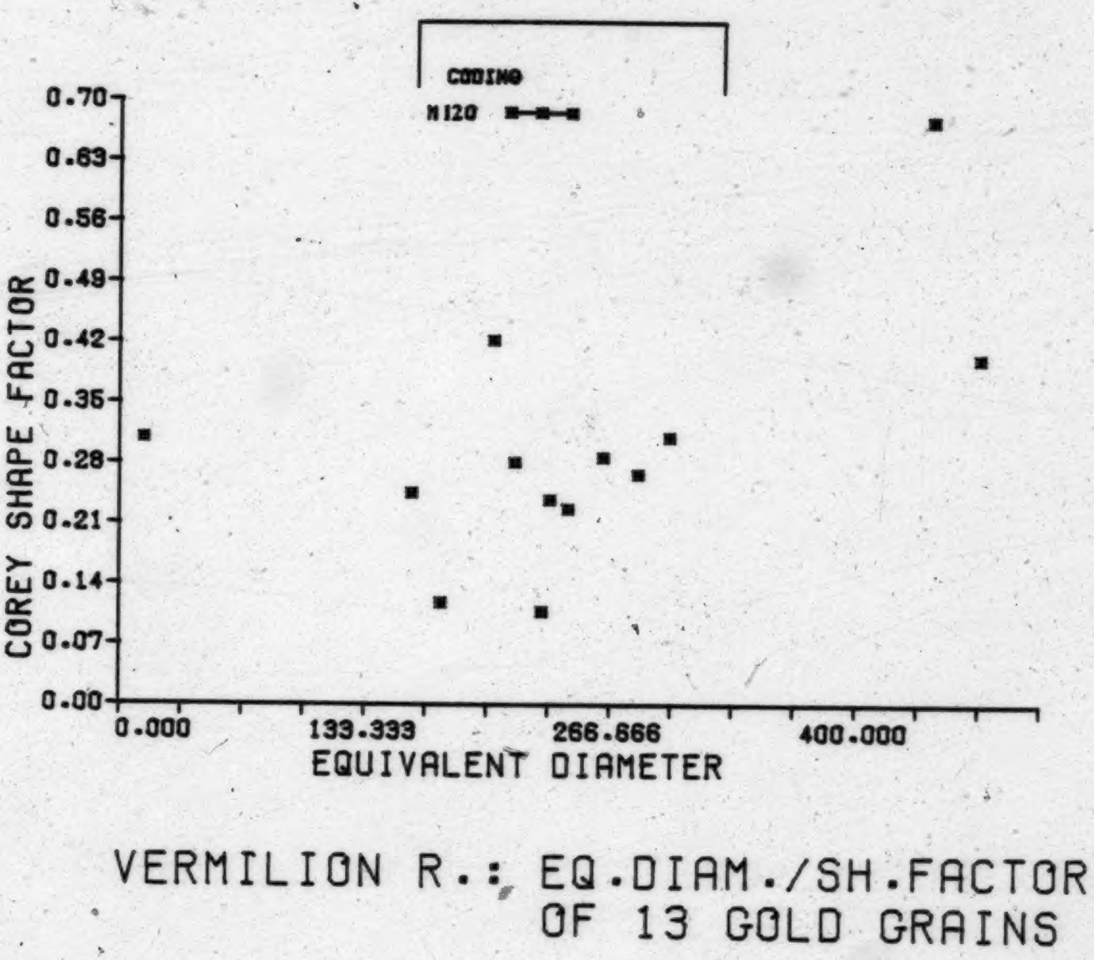


Figure 45: Diagram of shape factor versus equiv. diam.; Vermilion River

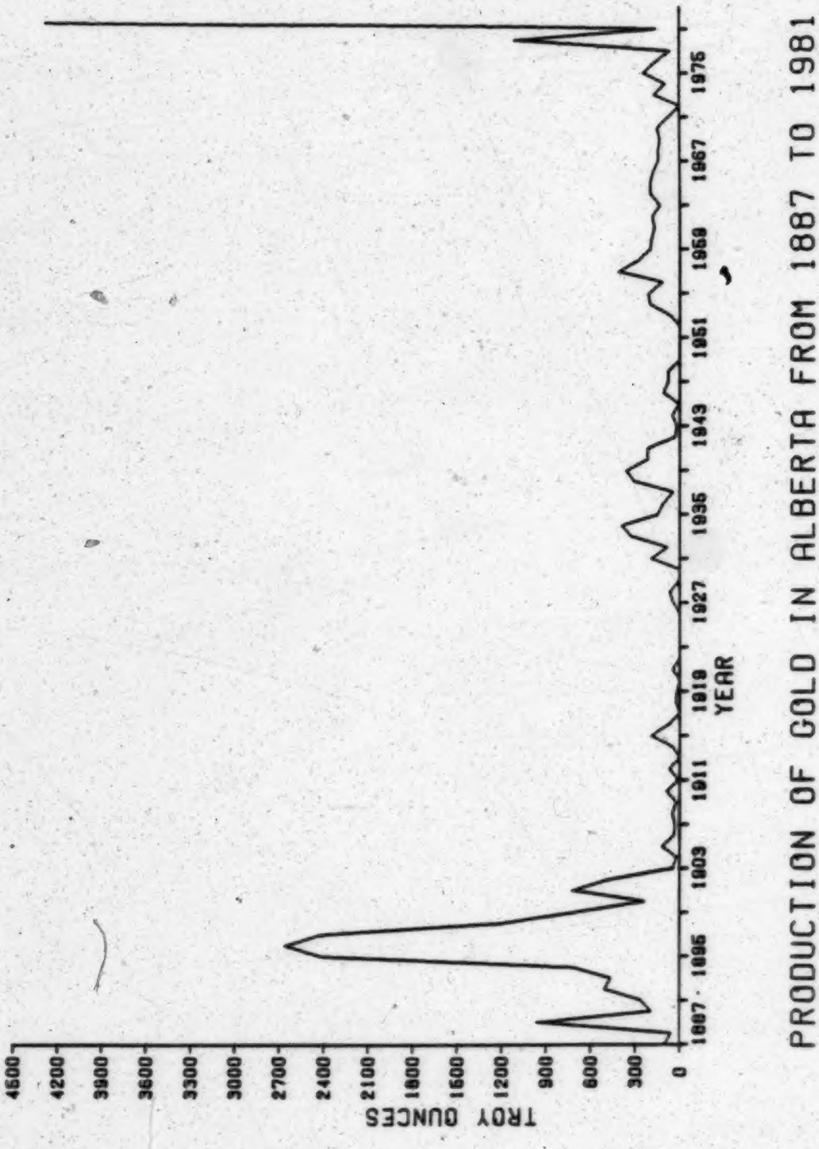


Figure 46: Production of gold in Alberta from 1887 to 1981

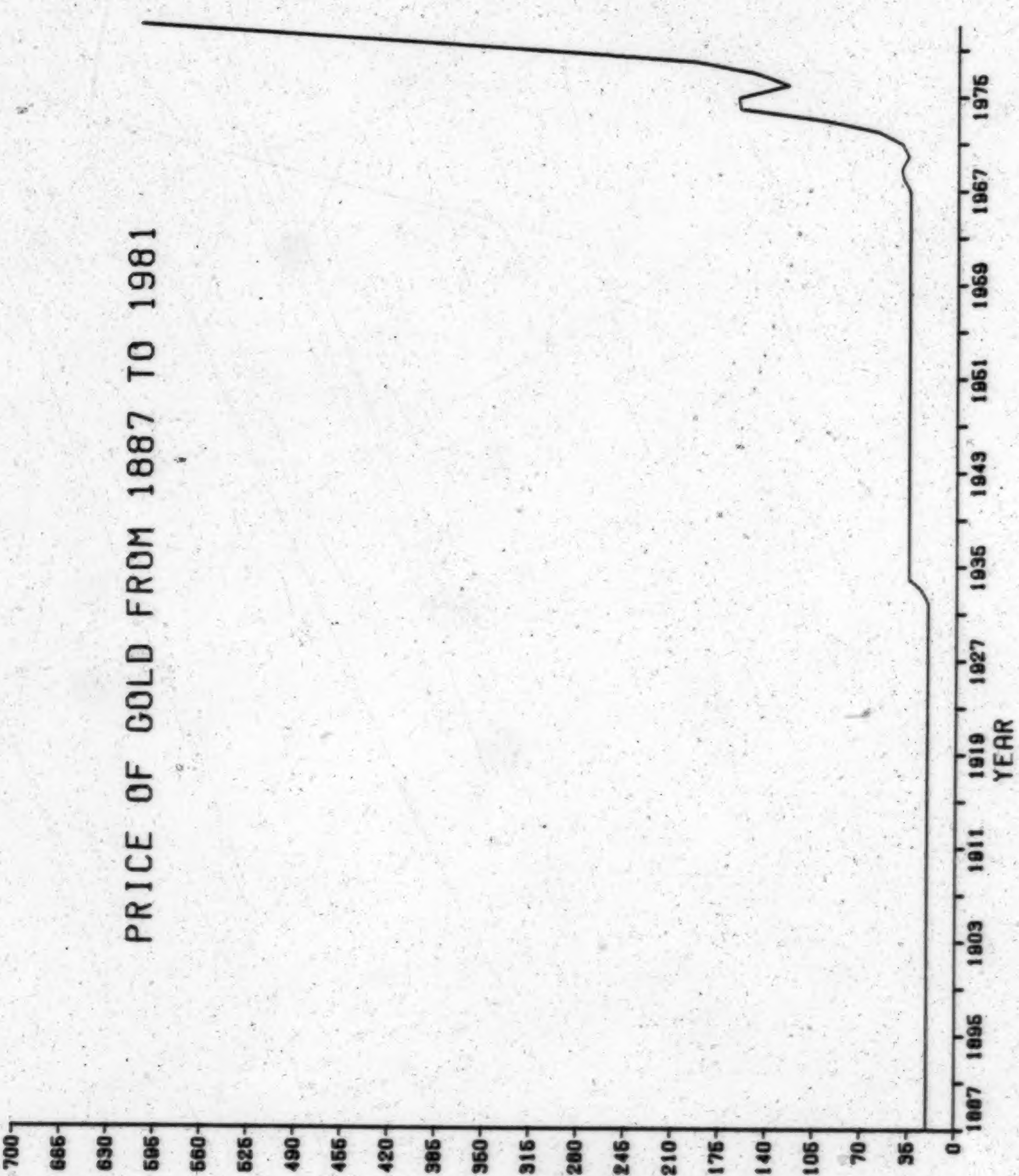
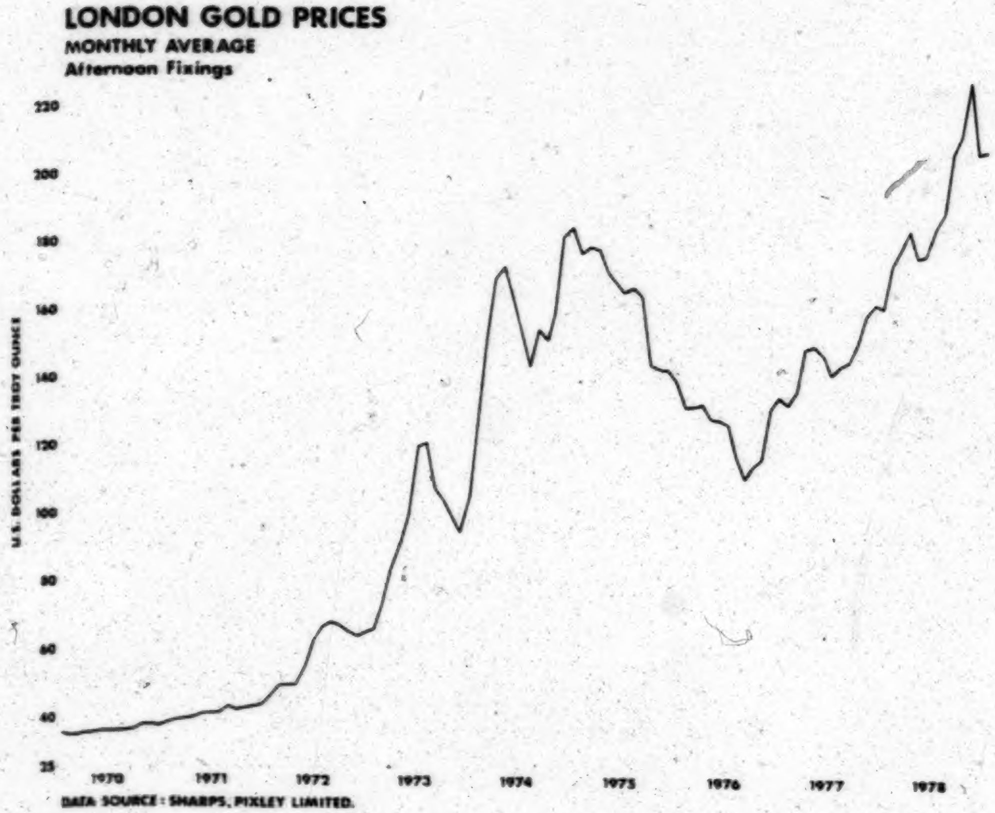
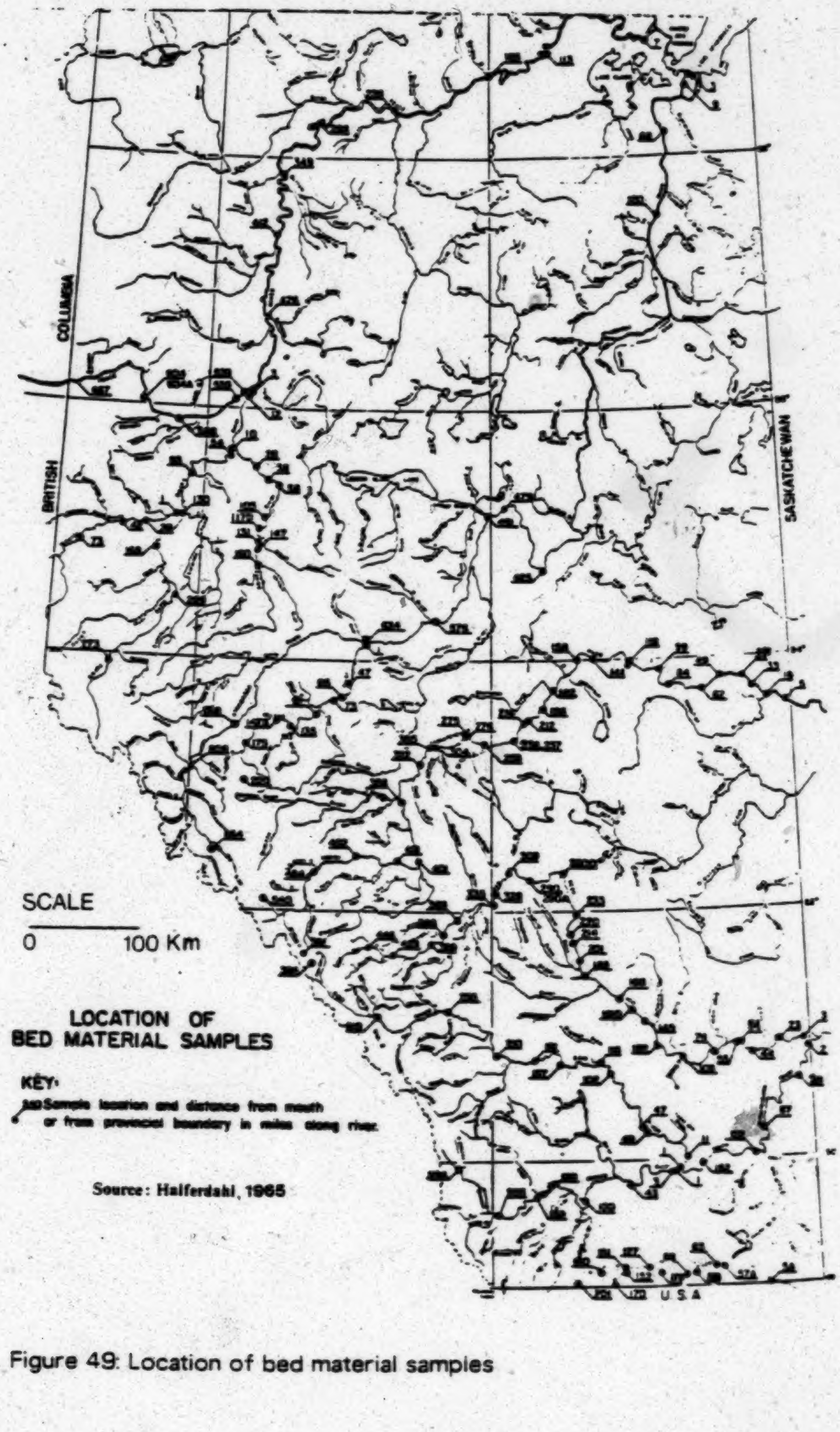


Figure 47: Price of gold in Alberta from 1887 to 1981



DATA SOURCE: SHARPS, PIXLEY LIMITED.

Figure 48: London gold prices. Monthly average


BRITISH
COLUMBIA
SASKATCHEWAN
U.S.A.
SCALE
0
100 Km
LOCATION OF
BED MATERIAL SAMPLES
KEY:
Sample location and distance from mouth
or from provincial boundary in miles along river.

Source: Halferdahl, 1965

Figure 49: Location of bed material samples

Gold Determinations - North Saskatchewan River

No.	Size Fraction (mesh)	Panned Concentrates	
		Volume Sampled cu ft	Gold Recovered mg/cu yd
5	18-35	5.1	
	35-60	5.1	nil
	-60	5.1	0.689
	Total		0.689
18	18-35	4.5	nil
	35-60	13.5	0.340
	60-120	13.5	13.320
	-120	13.5	57.240
	Total		70.900
33	18-35	4.5	nil
	35-60	13.5	0.100
	60-120	13.5	21.360
	-120	13.5	71.600
	Total		93.060
37	18-35	3.0	nil
	35-60	20.0	0.014
	60-120		7.040
	-120		2.050
	Total		9.104
49	18-35	4.5	nil
	35-60	13.5	0.100
	60-120	13.5	14.740
	-120	13.5	30.400
	Total		45.240
62	35-60	1.7	nil
	-60	16.6	61.000
	Total		61.000
62 Sieved	60-120		
	-120		
	Total		
62A	18-35	4.0	nil
	35-60	16.0	3.180
	60-120	16.0	31.100
	-120	16.0	134.500
	Total		168.780
84	18-35	4.0	nil
	35-60	16.0	4.035
	60-120	16.0	63.900
	-120	16.0	140.200
	Total		208.135
89	18-35	4.0	nil
	35-60	16.0	1.132
	60-120	16.0	11.390
	-120	16.0	38.340
	Total		50.862
118	35-60	2.0	nil
	-60	16.9	247.200
	Total		247.200
118 sieved	60-120		
	-120		
	Total		
118A	18-35	4.0	nil
	35-60	14.0	0.502
	60-120	14.0	25.250
	-120	14.0	114.800
	Total		140.552
141	18-35	8.0	nil
	35-60	20.0	1.823
	60-120	20.0	19.100
	-120	20.0	21.520
	Total		42.443
158	18-35	8.0	nil
	35-60	20.0	lost
	60-120	20.0	16.440
	-120	20.0	18.770
	Total		35.210
182	35-60	1.5	nil
	-60	16.4	16.250
	Total		16.250
182 sieved	60-120		
	-120		
	Total		
182A	18-35	8.0	nil
	35-60	20.0	0.074
	60-120	20.0	9.220
	-120	20.0	7.105
	Total		16.399
212	18-35	8.0	nil
	35-60	22.0	1.842
	60-120		10.680
	-120		10.580
	Total		23.102
236	-60	14.9	14.070
236 sieved	-60		
237	18-35	8.0	nil
	35-60	20.0	0.770
	-60	20.0	53.950
	Total		54.720
237 sieved	35-60		
	-60		
	Total		
253	18-35	8.0	nil
	35-60	20.0	0.635
	-60	20.0	5.238
	Total		5.873
276	18-35	8.0	nil
	35-60	20.0	0.081
	-60	20.0	0.446
	Total		0.527
304	35-60	3.1	nil
	-60	20.4	2.382
	Total		2.382
305	18-35	8.0	nil
	35-60	20.0	0.297
	-60	20.0	5.265
	Total		5.562
322	18-35	8.0	nil
	35-60	20.0	0.230
	-60	20.0	0.878
	Total		1.108
358	18-35	8.0	nil
	35-60	20.0	0.068
	-60	20.0	2.065
	Total		2.133
401	18-35	8.0	nil
	35-60	20.0	0.135
	60-120	20.0	2.052
	-120	20.0	1.485
	Total		3.672
421	18-35	8.0	nil
	35-60	20.0	nil
	-60	20.0	0.297
	Total		0.297
484	18-35	8.0	nil
	35-60	20.0	0.014
	-60	20.0	0.054
	Total		0.068
540	18-35		nil
	35-60		nil
	-60		nil
	Total		0.000

Source: HALFERDAHL, 1965

Figure 50: Gold determinations: North Saskatchewan River

Gold Determinations - Red Deer River

		Panned Concentrates	
No.	Size Fraction (mesh)	Volume Sampled cu ft	Gold Recovered mg/cu yd
3	18-35	5.0	
	35-60	5.0	nil
	-60	5.0	0.054
	Total		0.054
54	18-35	5.0	
	35-60	5.0	nil
	-60	5.0	2.754
	Total		2.754
103	18-35		
	35-60		
	-60		
	Total		
145	18-35	5.0	
	35-60	5.0	nil
	-60	5.0	0.108
	Total		0.108
161	18-35		
	35-60		nil
	-60		
	Total		
161D	18-35	4.0	
	35-60	16.0	0.169
	-60	16.0	6.598
	Total		6.767
161D Sieved	35-60		
	-60		
	Total		
168	18-35	8.0	nil
	35-60	20.0	nil
	60-120	20.0	0.648
	-120	20.0	2.052
	Total		2.700
189	18-35	8.0	
	35-60	20.0	0.378
	60-120	20.0	5.630
	-120	20.0	9.950
	Total		15.958
198	18-35		
	35-60		nil
	-60		
	Total		
201	18-35	5.0	
	35-60	5.0	nil
	60-120	5.0	0.432
	-120	5.0	1.080
	Total		1.512
214	18-35	8.0	
	35-60	20.0	0.162
	60-120	20.0	0.675
	-120	20.0	1.647
	Total		2.484
220	18-35	8.0	
	35-60	20.0	nil
	-60	20.0	3.132
	Total		3.132
220 sieved	35-60		nil
	-60		
	Total		
233	18-35	8.0	
	35-60	20.0	nil
	60-120	20.0	0.607
	-120	20.0	1.323
	Total		1.930
260A	35-60		
	-60		
	Total		
260B	35-60		nil
	-60		
	Total		
260C	35-60		
	-60		
	Total		
260D	18-35	8.0	
	35-60	20.0	0.135
	60-120	20.0	1.067
	-120	20.0	1.418
	Total		2.620
290	18-35	8.0	
	35-60	20.0	nil
	-60	20.0	1.242
	Total		1.242
309	18-35	8.0	
	35-60	20.0	nil
	-60		0.230
	Total		0.230
328A	18-35		
	35-60		
	-60		
	Total		
335	18-35	8.0	
	35-60	20.0	nil
	-60	20.0	2.390
	Total		2.390
386	-60	21.3	0.013
386 sieved	-60		nil
429	-60	17.0	0.025
429 sieved	-60		
446A	18-35		nil
	35-60		nil
	-60		nil
	Total		
446A sieved	60-120		nil
	120-230		nil
	-230		nil

Source: HALFERDAHL, 1965

Figure 51: Gold determinations: Red Deer River

Gold Determinations - Oldman River

No.	Size Fraction (mesh)	Panned Concentrates	
		Volume Sampled cu ft	Gold Recovered mg/cu yd
1	18-35	8.0	
	35-60	20.0	0.010
	60-120	20.0	0.162
	120-230		
	-230		
	Total		0.172
3	18-35		
	35-60		
	60-120		
	120-230		
	-230		
	Total		very little
43	18-35		
	35-60		nil
	60-120		
	120-230		
	-230		
	Total		
43D	18-35	not collected	
	35-60	10.0	0.108
	60-120	10.0	0.189
	120-230	10.0	0.432
	-230		
	Total		0.729
100	18-35		nil
	35-60		
	60-120		
	120-230		
	-230		
	Total		
158	18-35		
	35-60		nil
	60-120		
	120-230		
	-230		
	Total		
159	18-35	not collected	
	35-60	10.0	nil
	60-120	10.0	0.810
	120-230	10.0	0.405
	-230		
	Total		1.215
205	18-35		
	35-60		nil
	60-120		nil
	120-230		
	-230		
	Total		
256	18-35		nil
	35-60		nil
	60-120		nil
	120-230		
	-230		
	Total		

Source HALFERDAHL, 1965

Figure 52: Gold determinations: Oldman River

Gold Determinations – Smoky River

		Panned Concentrates	
No.	Size Fraction (mesh)	Volume Sampled cu ft	Gold Recovered mg/cu yd
3	-60	14.9	1.359
12	18-35	8.0	nil
	35-60	20.0	0.014
	-60	20.0	0.756
	Total		0.770
54	18-35	8.0	nil
	35-60	20.0	0.027
	-60	20.0	1.107
	Total		1.134
93	18-35	8.0	nil
	35-60	20.0	0.149
	-60	20.0	1.931
	Total		2.080
130	18-35	8.0	nil
	35-60	20.0	nil
	-60	20.0	0.878
	Total		0.878
168	18-35	8.0	nil
	35-60	20.0	0.014
	-60	20.0	0.095
	Total		0.109
	18-35		
	35-60		
	-60		
	Total		
273	18-35	8.0	nil
	35-60	20.0	nil
	-60	20.0	nil
	Total		nil

Source: Halferdahl, 1965

Figure 53: Gold determinations: Smoky River

Gold Determinations - Wapiti River

		Panned Concentrates	
No.	Size Fraction (mesh)	Volume Sampled cu ft	Gold Recovered mg/cu yd
1	18-35	8.0	nil
	35-60	20.0	0.378
	-60	20.0	0.905
	Total		1.283
20	18-35	not collected	
	35-60		
	60-120 120-230 -230		
	Total		
42	18-35	not collected	
	35-60		nil
	60-120 120-230 -230		
	Total		
73	18-35	6.0	nil
	35-60	18.0	0.495
	-60	18.0	0.030
	Total		0.525

Source: HALFERDAHL, 1965

Figure 54: Gold determinations: Wapiti River

Gold Determinations - South Saskatchewan River

		Panned Concentrates	
No.	Size Fraction (mesh)	Volume Sampled cu ft	Gold Recovered mg/cu yd
2	18-35	8.0	nil
	35-60	20.0	0.176
	-60	20.0	0.756
	Total		0.932
28	18-35	8.0	nil
	35-60	20.0	nil
	-60	20.0	5.981
	Total		5.981
87	18-35	8.0	nil
	35-60	20.0	0.014
	-60	20.0	0.716
	Total		0.730
122	18-35	8.0	nil
	35-60	20.0	nil
	-60	20.0	0.446
	Total		0.446
162	18-35	8.0	nil
	35-60	20.0	nil
	-60	20.0	1.148
	Total		1.148

Source: HALFERDAHL, 1965

Figure 55: Gold determinations: South Saskatchewan River

Gold Determinations - Athabasca River

No.	Size Fraction (mesh)	Panned Concentrates	
		Volume Sampled cu ft	Gold Recovered mg/cu yd
9	35-60	4.2	nil
	-60	4.2	0.060
	Total		0.060
425	18-35	not collected	
	35-60		
	60-120		
	120-230		
	-230		
	Total		
479	18-35	3.0	nil
	35-60	3.0	nil
	60-120	3.0	0.630
	-120	3.0	0.630
	Total		1.260
491	18-35		
	35-60		
	60-120		
	120-230		
	-230		
	Total		
576	-60	19.3	0.896
634	-60	17.3	0.078
748	18-35	not collected	
	35-60		
	60-120		
	120-230		
	-230		
	Total		
808	18-35	not collected	
	35-60		nil
	60-120		
	120-230		
	-230		
	Total		
854	-60	14.9	0.018

Source:
HALFERDAHL, 1965

Figure 56: Gold determinations: Athabasca River

Gold Determinations - McLeod River

No.	Size Fraction (mesh)	Panned Concentrates Volume Sampled cu ft	 Gold Recovered mg/cu yd
1	18-35	1.2	nil
	35-60	1.2	nil
	-60	18.2	0.089
	Total		0.089
47	18-35	1.2	nil
	35-60	1.2	0.022
	-60	16.1	1.493
	Total		1.515
65	18-35	8.0	nil
	35-60	20.0	nil
	-60	20.0	1.255
	Total		1.255
73	18-35	8.0	nil
	35-60	20.0	nil
	-60	20.0	1.013
	Total		1.013
91	18-35	1.2	nil
	35-60	1.2	nil
	-60	18.2	1.068
	Total		1.068
135	18-35	1.2	nil
	35-60	1.2	3.150
	60-120	22.5	6.910
	-120		
	Total		10.060
135A	35-60	9.0	0.240
	60-120	9.0	7.650
	-120	9.0	7.650
	Total		15.540
147B	35-60	5.0	0.811
	60-120	5.0	2.863
	-120	5.0	2.053
	Total		5.727
175	-60	17.0	0.111
220	-60	17.0	0.015

Source:
HALFERDAHL, 1965

Figure 57: Gold determinations: McLeod River

Gold Determinations - Peace River

No.	Size Fraction (mesh)	Panned Concentrates: Volume Sampled cu ft	Panned Concentrates: Gold Recovered mg/cu yd
7	35-60	4.2	nil
	-60	4.2	0.514
	Total		0.514
60	35-60	4.2	nil
	-60	4.2	0.060
	Total		0.060
113	35-60	4.2	nil
	-60	4.2	0.386
	Total		0.386
165	35-60	4.2	nil
	-60	4.2	nil
	Total		0.000
228	35-60	4.2	nil
	-60	4.2	0.060
	Total		0.060
288	35-60	4.2	nil
	-60	4.2	0.060
	Total		0.060
349	35-60	1.7	nil
	60-120	16.6	7.075
	-120		
	Total		7.075
412	60-120	14.9	0.236
	-120		
	Total		0.236
476	60-120	16.8	1.125
	-120		
	Total		1.125
538	18-35	8.0	
	35-60	20.0	0.014
	60-120	20.0	0.891
	-120		
	Total		0.905
539	60-120	14.9	1.323
	-120		
	Total		1.323
588	35-60		
	60-120		
	-120		
	Total		
604	60-120	16.8	2.475
	-120		
	Total		2.475
604A	18-35	8.0	
	35-60	20.0	0.338
	60-120	20.0	1.242
	-120		
	Total		1.680
667	60-120	16.8	0.193
	-120		
	Total		0.193

Source:
HALFERDAHL, 1965

Figure 58: Gold determinations: Peace River

Gold Determinations - Bow River

No.	Size Fraction (mesh)	Panned Concentrates Volume Sampled cu ft	Panned Concentrates Gold Recovered mg/cu yd
	18-35	4.5	nil
	35-60	13.5	nil
11	60-120	13.5	0.240
	-120	13.5	0.500
	Total		0.740
	18-35	3.0	nil
	35-60	12.0	0.045
49	60-120	12.0	1.125
	-120	12.0	0.631
	Total		1.801

Source: Halferdahl, 1965

Figure 59: Gold determinations: Bow River

Gold Determinations - North Milk River

		Panned Concentrates	
No.	Size Fraction (mesh)	Volume Sampled cu ft	Gold Recovered mg/cu yd
151	18-35	4.0	nil
	35-60	16.0	nil
	-60	16.0	1.248
	Total		1.248
180	18-35	8.0	nil
	35-60	20.0	nil
	-60	20.0	0.852
	Total		0.852
201	18-35	8.0	nil
	35-60	20.0	0.230
	-60	20.0	0.365
	Total		0.595

source: Halferdahl, 1965

Figure 60: Gold determinations: North Milk River

Gold Determinations - Milk River

		Panned Concentrates	
No.	Size Fraction (mesh)	Volume Sampled cu ft	Gold Recovered mg/cu yd
5	35-60		nil
	-60		
	Total		
57	18-35		nil
	35-60		nil
	-60		
	Total		
117	18-35		nil
	35-60		nil
	60-120		
	-120		
	Total		
117E	35-60	9.0	0.210
	60-120	9.0	3.300
	-120	9.0	12.390
	Total		15.900
127	35-60	9.0	nil
	60-120	9.0	0.150
	-120	9.0	0.810
	Total		0.960
152	18-35	8.0	nil
	35-60	20.0	0.027
	-60		0.243
	Total		0.270
170	18-35		nil
	35-60		nil
	60-120		
	120-230		
	-230		

Source:

Halferdahl, 1965

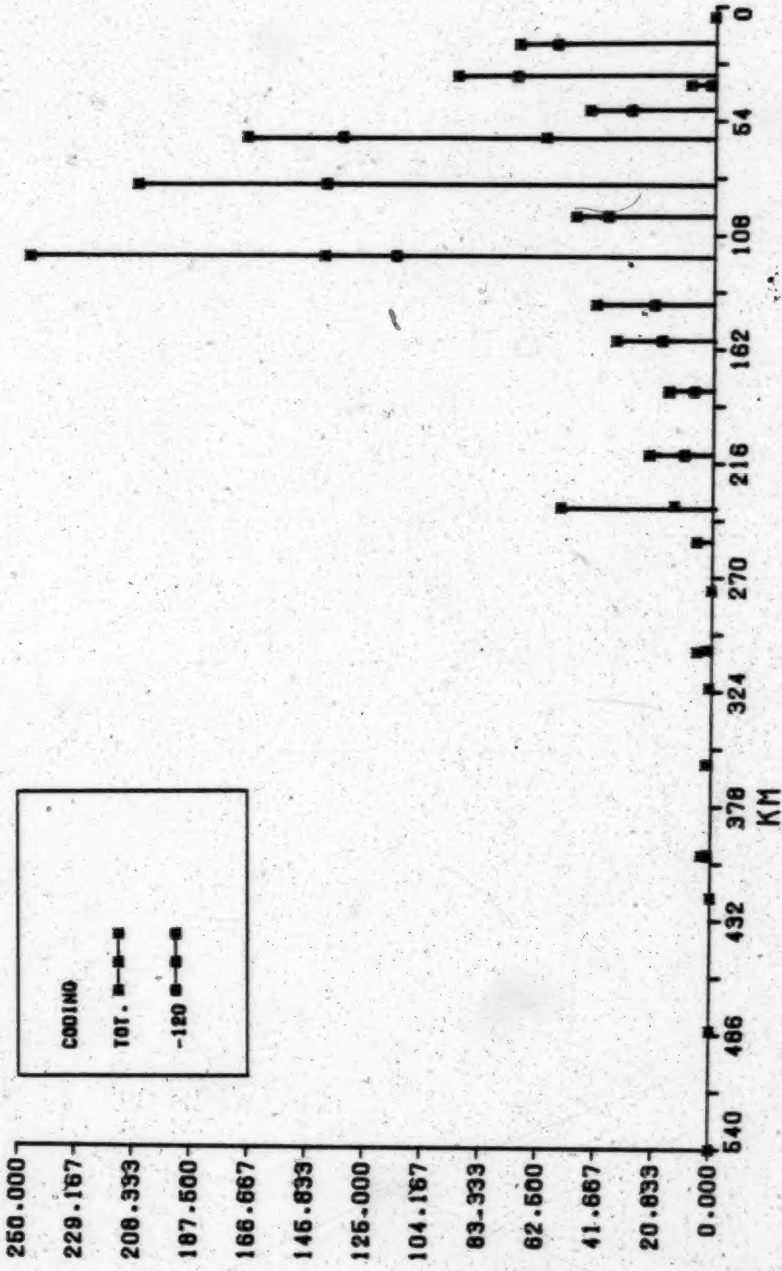
Figure 6.1: Gold determinations: Milk River

Samples in which Platinum was noted

McLeod	135A	60-120, -120
	147B	-120
Milk	117E	-120
North Sask.	18	60-120, -120
	33	60-120, -120
	37	-120
	49	60-120
	62	-120
	62A	60-120, -120
	84	60-120, -120
	99	60-120, -120
	118	-60, -120
	118A	60-120, -120
	141	60-120, -120
	182	-60
	212	60-120, -120
	236	-60
	276	-60
South Sask.	28	-60 ?
Red Deer	54	-60
	189	-120

Source: Halferdahl, 1965

Figure 62: Samples in which platinum was noted



NORTH SASKATCHEWAN RIVER:
GOLD DETERMINATIONS

Figure 63: Plot of gold content in samples from the North Saskatchewan River

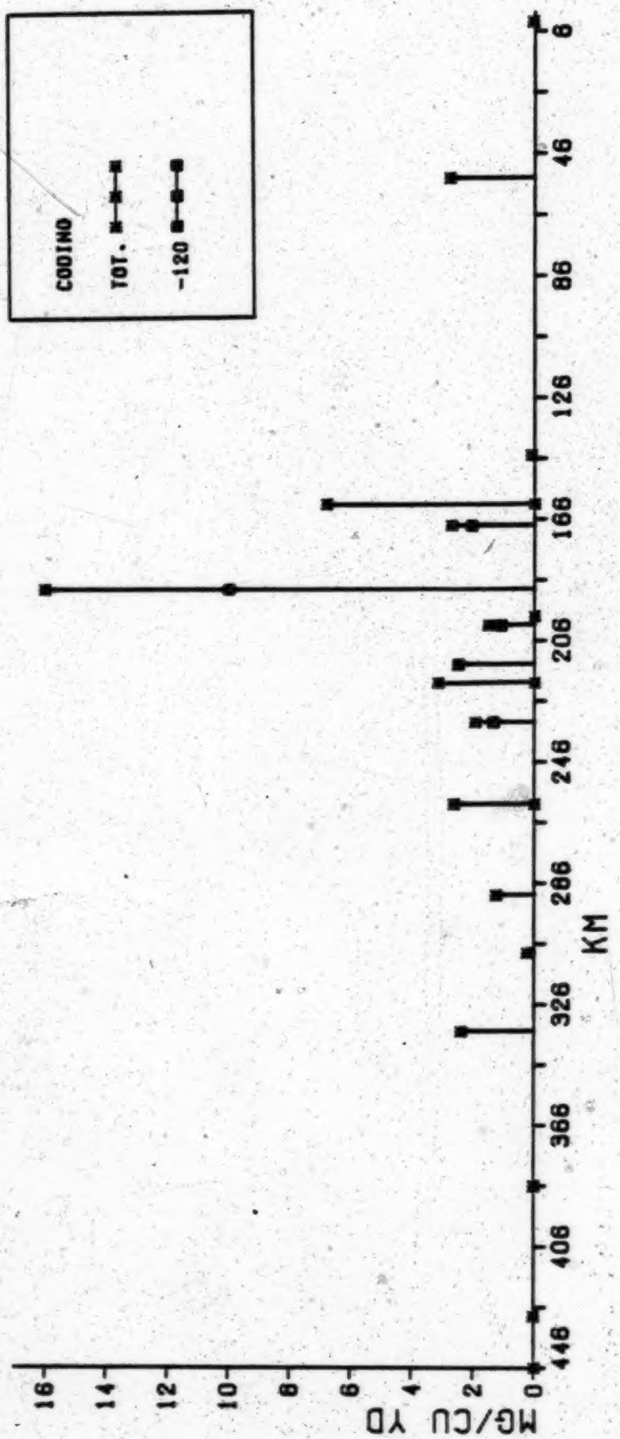
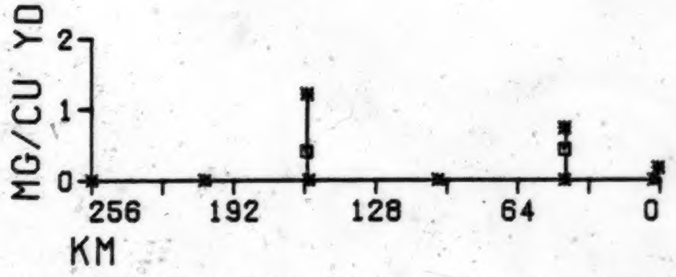
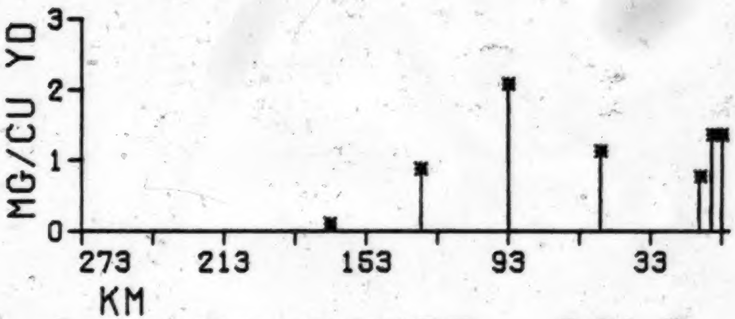


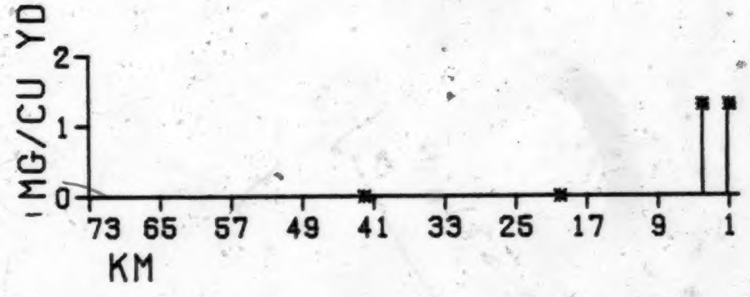
Figure 64. RED DEER RIVER:
GOLD DETERMINATIONS



OLDMAN RIVER: GOLD DETERMINATIONS



SMOKY RIVER: GOLD DETERMINATIONS



WAPITI RIVER: GOLD DETERMINATIONS

Figure 65: Plot of gold content in samples from the Oldman River, the Smoky River and the Wapiti River

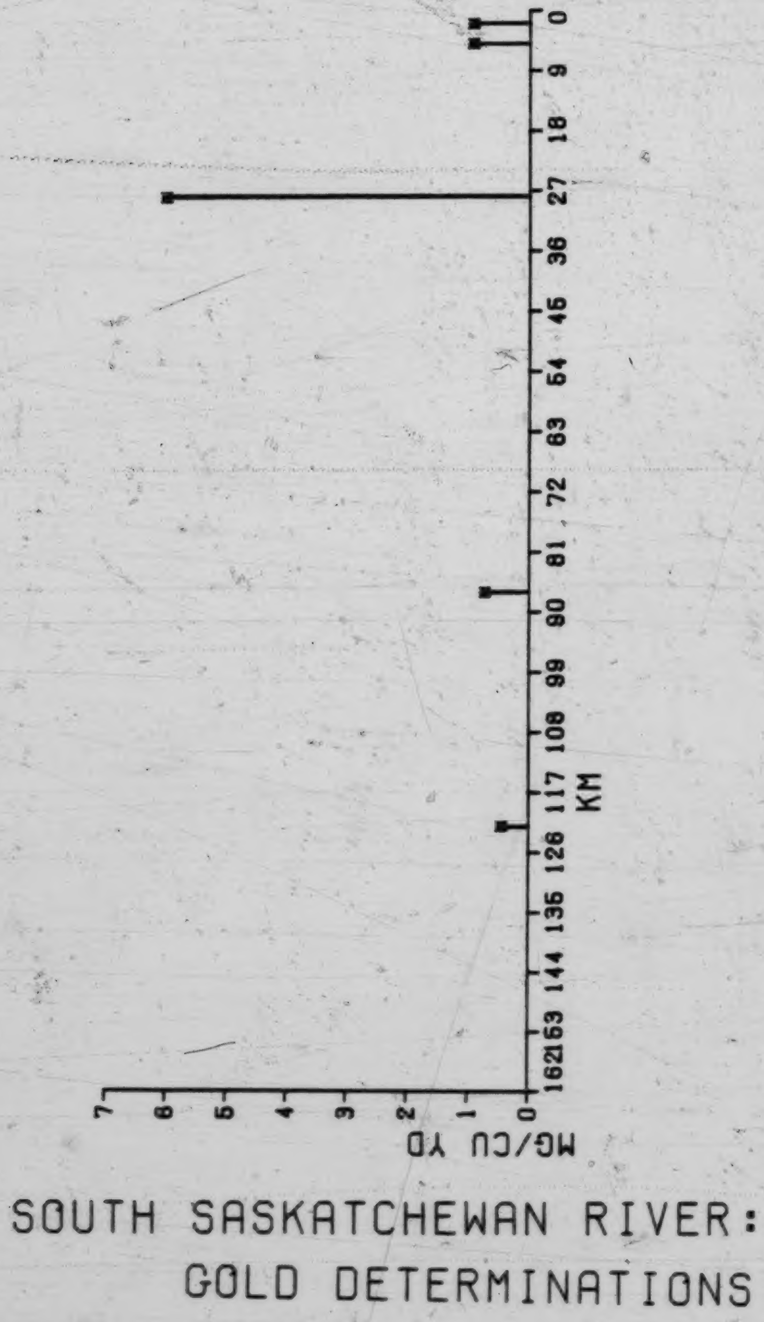


Figure 66: Plot of gold content in samples from the South Saskatchewan River

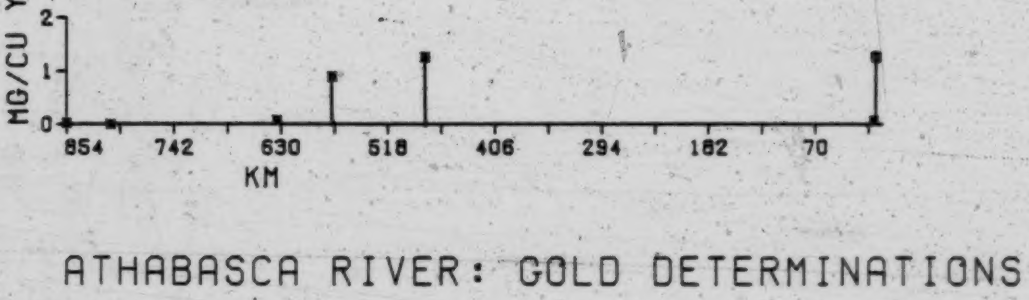


Figure 67: Plot of gold content in samples from the Athabasca River

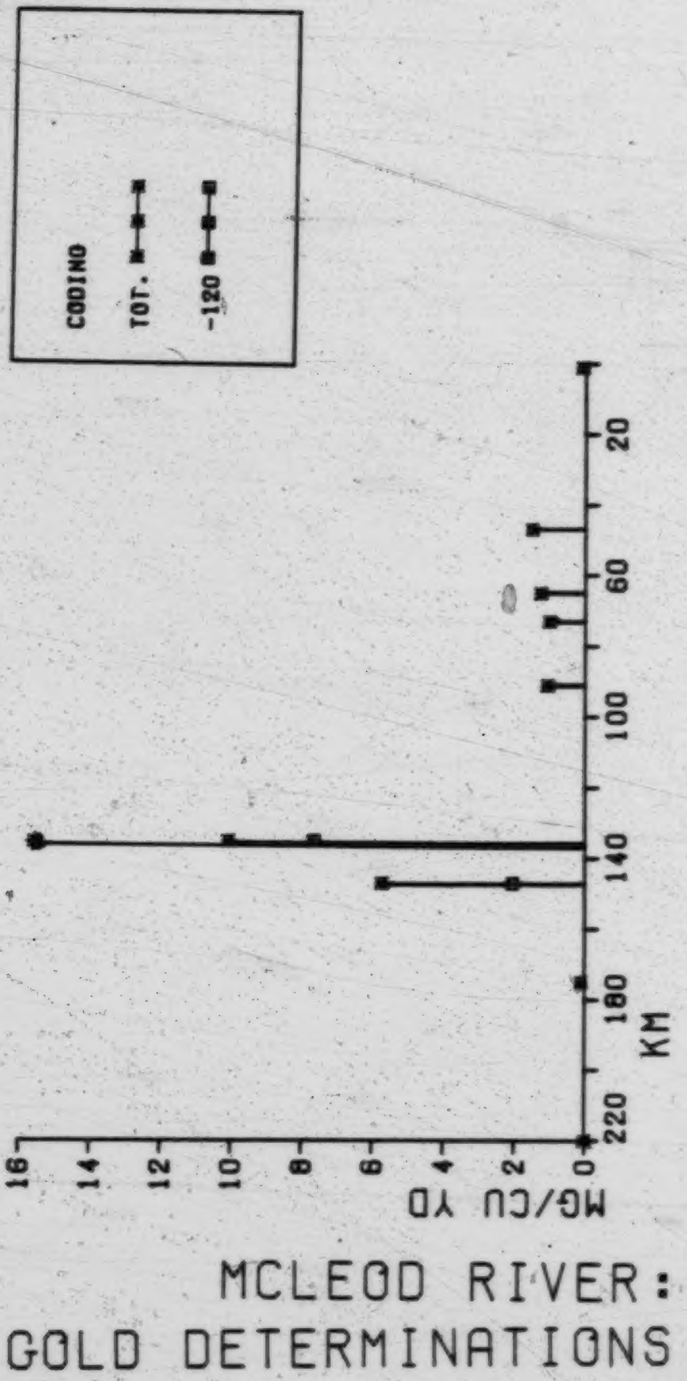


Figure 68: Plot of gold content in samples from the McLeod River

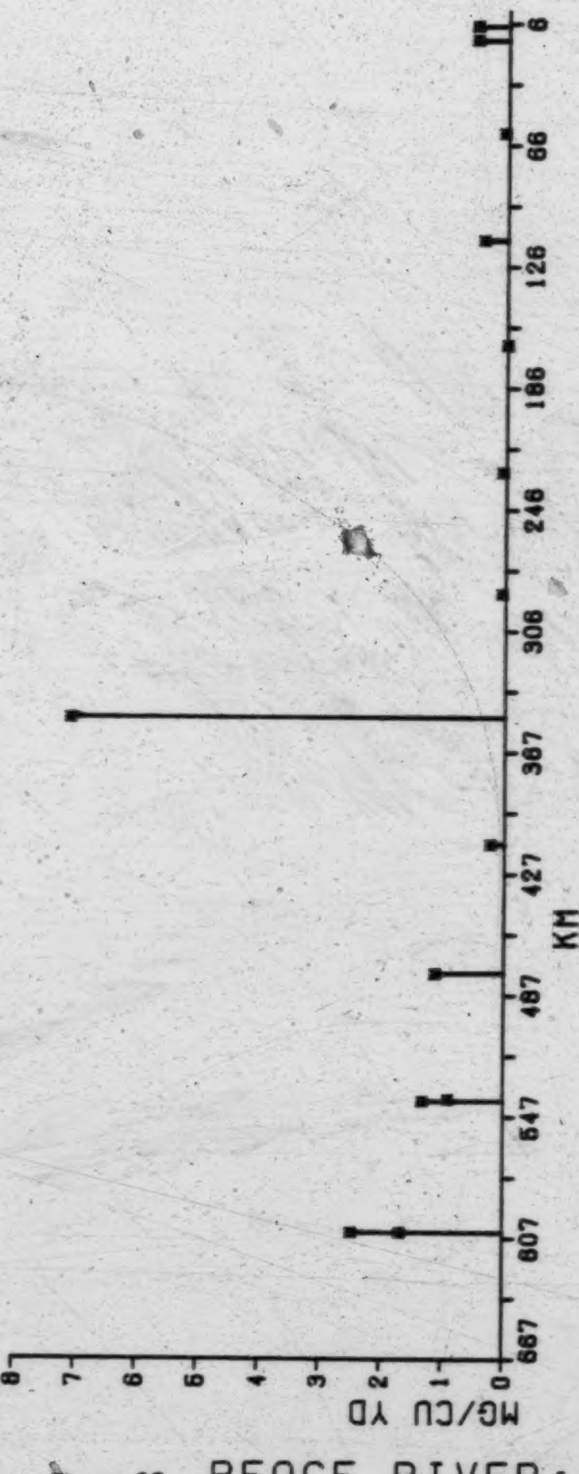


Figure 69. PEACE RIVER: GOLD DETERMINATIONS

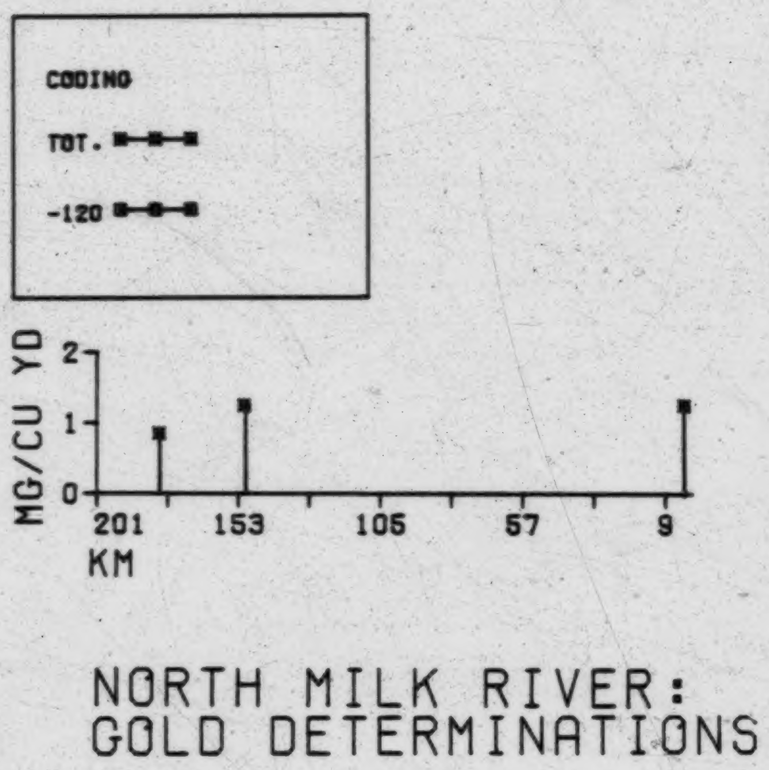


Figure 70: Plot of gold content in samples from the North Milk River

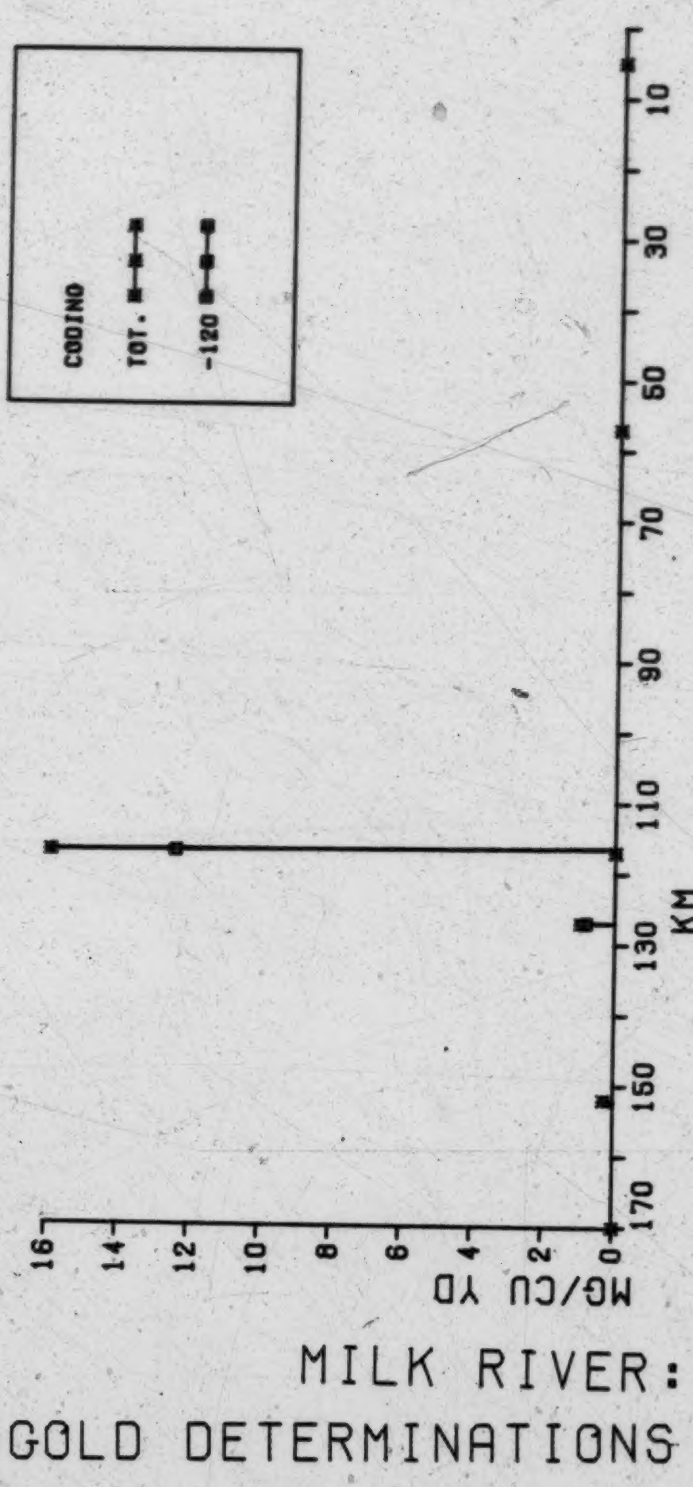
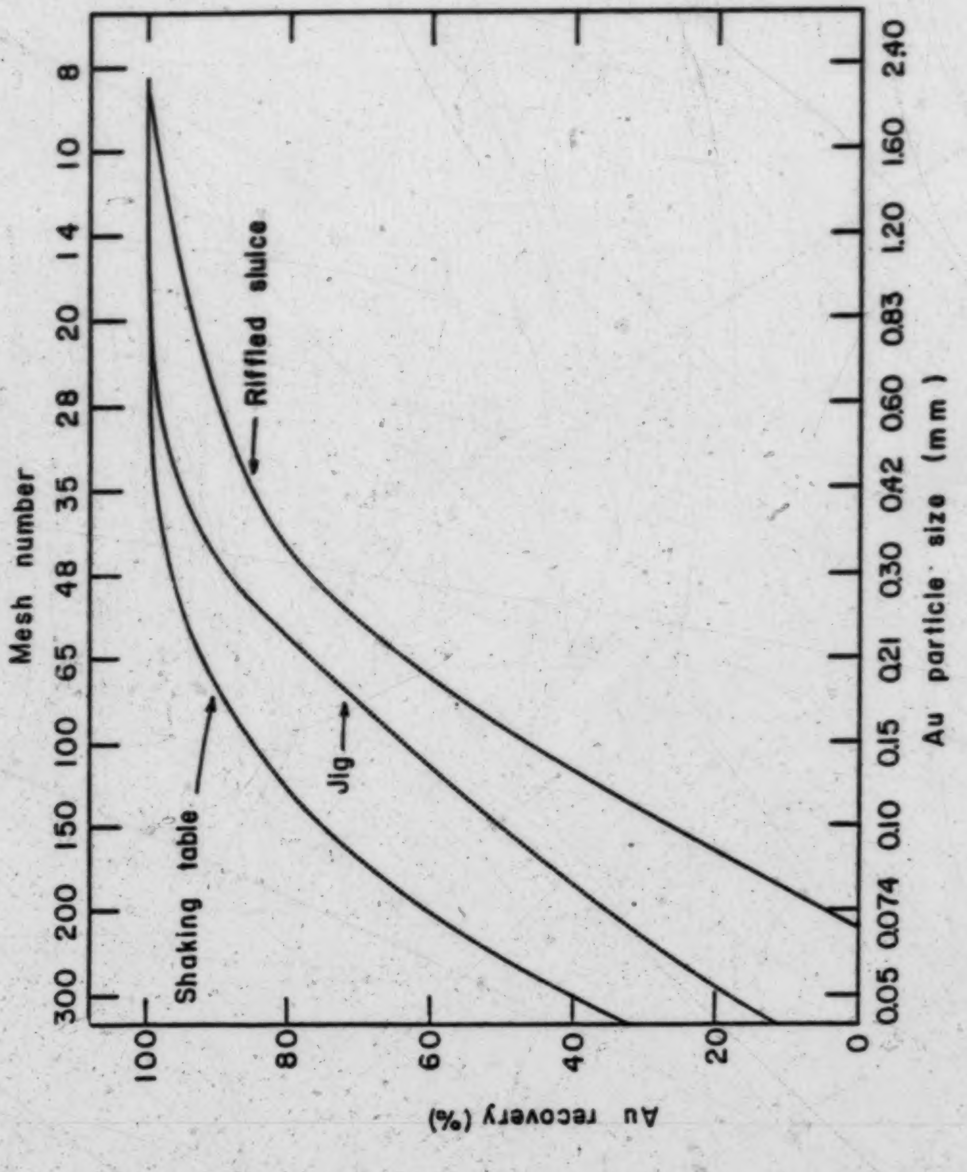
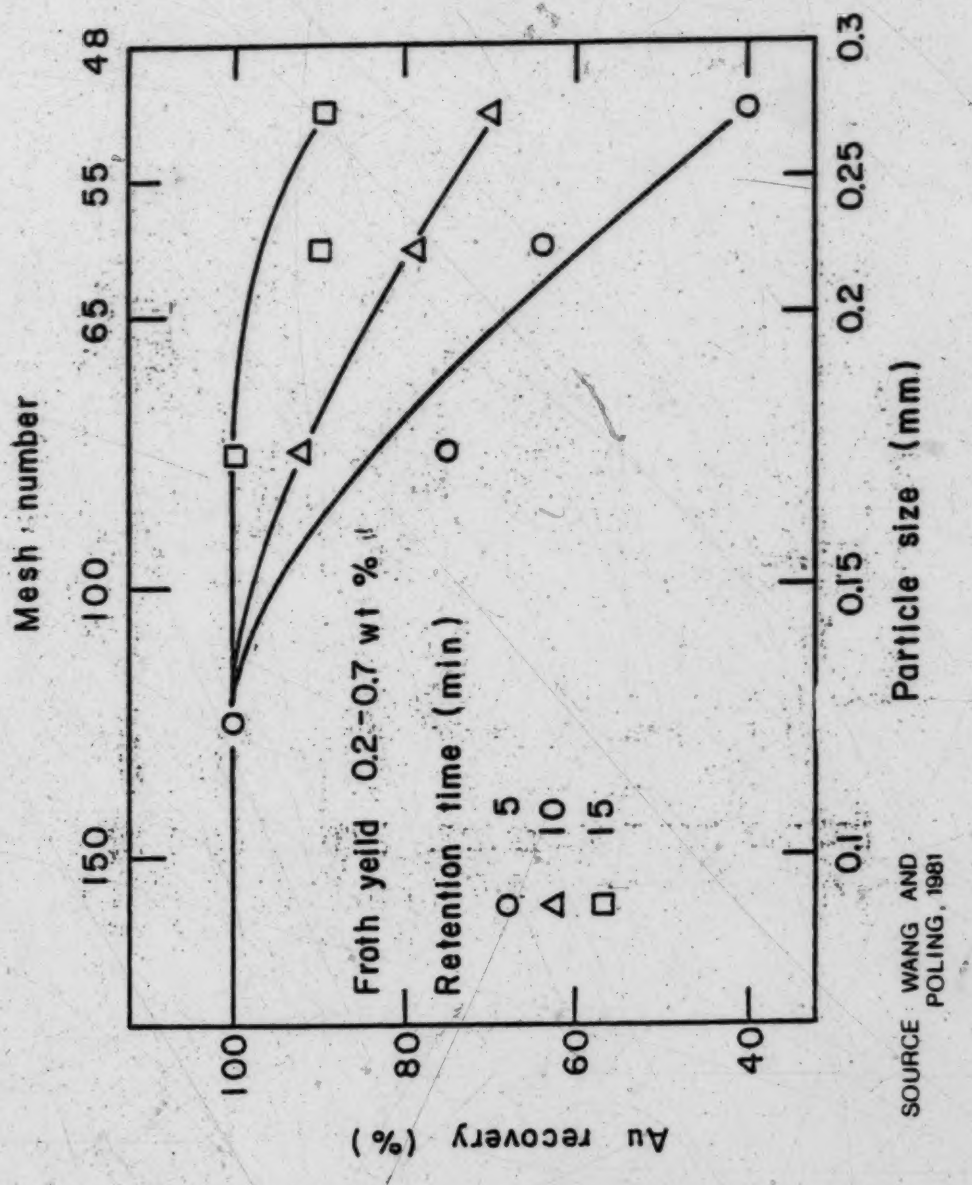


Figure 71: Plot of gold content in samples from the Milk River



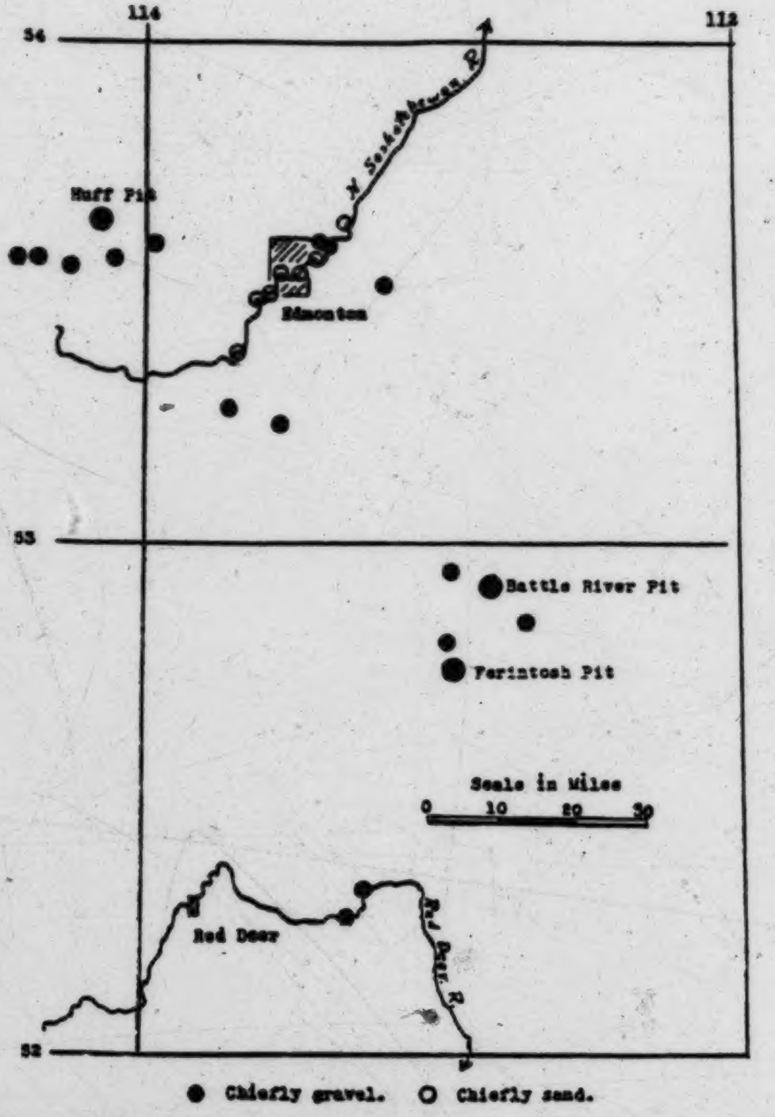
RECOVERY OF DIFFERENT SIZE Au PARTICLES
BY GRAVITY DEVICES (WANG, 1979)

Figure 72: Diagram showing the efficiency of gravity devices in recovering gold



RELATIONSHIPS BETWEEN AU PARTICLES
SIZE AND FLOTATION RECOVERY

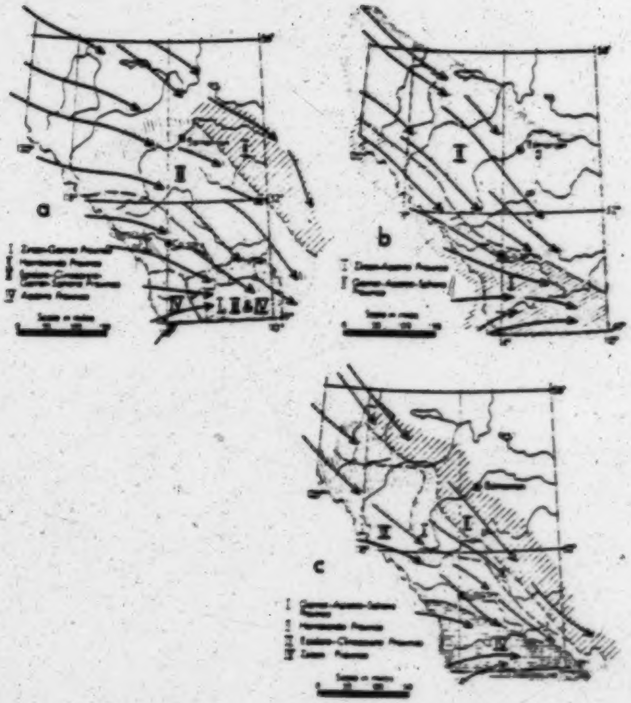
Figure 73: Diagram showing the relationship between gold-particle size and flotation recovery


114
112
54
53
52
N. Saskatchewan R.
Huff Pit
Edmonton
Battle River Pit
Ferintosh Pit
Scale in Miles
0
10
20
30
Red Deer
Red Deer R.
● Chiefly gravel.
O Chiefly sand.

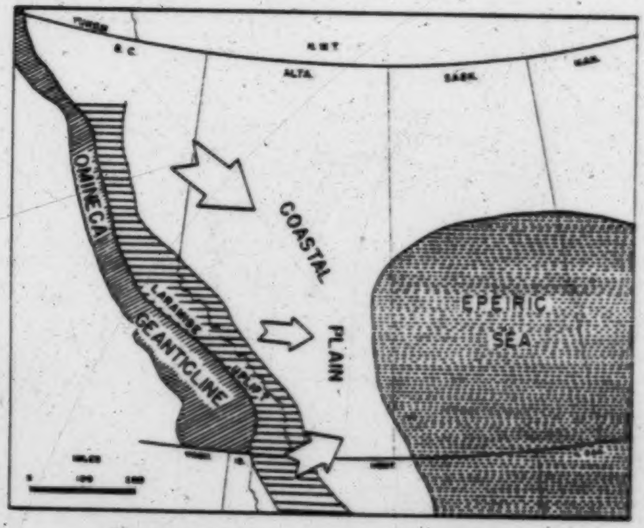
Distribution of Saskatchewan gravel and sand deposits in part of central Alberta.

Source: Rutherford, 1937

Figure 74: Distribution of Saskatchewan gravel and sand deposits in part of Central Alberta


a
b
c
I
II
IV
I,II & IV

Heavy-mineral provinces and dispersal directions. a. Belly River ; b. Edmonton ; c. Paskapoo.


B.C.
N.W.T.
ALTA.
SASK.
MAN.
OMINECA
LARAMIDE
GEANTICLINE
COASTAL
PLAIN
EPEIRIC
SEA
MILES

Generalized representation of the average palaeogeography and dispersal during Late Cretaceous and Paleocene times.

Source: Rahmani and
Lerbekmo, 1975

Figure 75: Heavy mineral provinces and dispersal directions during Late Cretaceous and Paleocene times

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VIII. Appendix I. Placers and modification of placers by glaciation

Placer deposits

According to Parker (1974) a *placer deposit* or *placer* is a deposit or accumulation of rock waste formed by natural processes of sedimentation, mass-wasting or weathering which mechanically brought about a relative concentration of gold or other heavy minerals.

Eluvial placer deposits (Fig. 28) are those which lie on or very near their source; natural mechanical processes (mainly elutriation) concentrated gold and other heavy minerals. They form in the weathered area and/or downhill from the primary auriferous deposit and are composed of debris not transported by streams. In the Russian literature eluvial placers are further subdived into *eluvial s.s.*, *deluvial (talus)* and *proluvial*; the first type is located in the area of the primary deposits, the second, downhill from the first one and down to foot of cliffs or steep slopes (talus or scree) where the proluvial upper limit starts.

Colluvial placer deposits lie some distance from their source and concentration has been brought about mainly by mass-wasting processes (landslides, earthflows, creep, etc.) due to the action of gravity.

Watershed placers are abandoned or dead valleys which contain in their alluvium placers which escaped destruction.

Alluvial placer deposits are formed by the action of running water; they can be subdivided in two main types: *autochthonous* and *allochthonous*. Placers of the first kind are formed of relatively coarse grains concentrated at the base of alluvial horizons and in crevices of the bedrock. In this category of placers there are two different main clastic fractions: a "passive fraction", relatively immobile, hardly moved by stream action, and an "active fraction", slowly carried downstream by the river.

There are transitions between the above mentioned classes, and the size of the particles of both classes varies in relation to hydrodynamic conditions. There are three main stages in the cycle of a stream valley erosion:

1. River downcutting;
2. Dynamic equilibrium;
3. Aggradation.

The corresponding deposits to these stages are named, in the Russsian literature, as: *instrative, perstrative* and *constrative* deposits, respectively. Downcutting is accompanied by rewashing of alluvium and settling of placer minerals to the bedrock. After the first stage and before the second there is the formation of the so-called "alluvium of normal thickness". The overlying strata can be washed, but those below the level of maximum depth of the river are protected.

According to Karstashov (1971) two types of autochthonous placers can be distinguished: *bottom* and *above-bottom*; the first category is due to long-term accumulation at the base of instrative (downcutting stage) or substrative (equilibrium and aggradation stages) alluvium and in crevices of bedrock.

The bedrock is reached only during downcutting and new minerals coming from primary ore deposits are deposited herein only at this stage. Material eroded from exposed ore deposits or terraces during an equilibrium and/or aggradation stage cannot reach the substrative (perstrative) alluvium but it can form autochthonous placers at the base of the perstrative alluvium and or within the constrative series. They are called above-bottom placers. This distinction is very important because in the first case the accumulation lasts for a long period of time thus producing rich placers, whereas in the second case the placers are due to short-term concentration and are smaller and poorer. Alluvial material deposited during many stages of a stream cycle is then typical of bottom placers, and mineral grains carried during the last equilibrium or aggradation stage are present in above-bottom placers.

A particular example of bottom placer is formed when materials present in rewashed strata containing above-bottom placers are deposited forming a relatively rich placer, which is called *false bedrock*. During a new erosion cycle downcutting may start again and bottom placers may be reached with the result that they receive material present in the upper layers and in the above-bottom placers. By contrast, they lose fine grains and some "active" fraction. Many cases have been observed in which terrace placers (produced by tributaries) have been redeposited by the main river without downstream displacement, even when the vertical displacement of gold was relevant; the gold placer just stretches across the main stream channel, looking exactly like a continuation of the original terrace placer. If lateral migration of the tributaries occurs, arms of the original "tributaries" placers still remain.

The old terms *channel placers* and *valley placers* are connected with land forms. Above-bottom and allochthonous placers cannot form during downcutting, so the channel placers occur only among bottom placers. The term valley placers can be applied to both autochthonous (bottom and above-bottom) and allochthonous placers. Therefore, the new subdivision proposed by the Russian authors is independent of land forms.

Grains dispersed from autochthonous placers can be reconcentrated in allochthonous placers if well defined hydrodynamic conditions are satisfied. They form on the surfaces of point-bars and channel bottoms when the water does not remove sufficient quantities of lighter minerals or when it removes both light materials and large quantities of "placer" minerals. They never form in downcutting parts of the river, but only during the dynamic equilibrium stage and particularly favourable is the stage of aggradation.

Modification of placers by glaciation

Glaciation is generally known to destroy preexisting placer deposits, dissipating the gold and other valuable heavy minerals. Interesting concentrations of gold are rare in glacial deposits such as eskers, kames, moraines, outwash deposits, etc. Glaciation does not preclude placer concentrations; glacial deposits may be eroded and reworked by post-glacial streams which may reconcentrate, to a certain extent, the dissipated precious metals. Many placers in B.C. originated in such a manner. The Canadian Shield and other flat regions of

Canada have been swept by ice sheets which scattered the eroded material over thousands of kilometres of ice fronts. The gold dissipated in such a manner is very difficult to reconcentrate. However, different conditions existed in the Cordilleran region; in particular it is important to point out that glacial erosion and dissipation were forced to occur within valley boundaries so that the chances of postglacial reconcentration are higher. Valleys of tributary streams were probably crossed by ice masses moving in directions approximately perpendicular to their channels or covered by stagnant ice caps, which protected original placers from being destroyed. It is then possible that thick layers of overburden are now covering pre-glacial deposits in the Cordillera. There are three kinds of glacially modified placers (Parker, 1974): *subglacial, marginal meltwater channel,* and *outwash deposits.*

During the advance of a valley glacier, all preglacial placer deposits are removed in the strongly abraded area upstream from the point where the glacier's surface rises above the snow-line. Downstream from here and particularly near the location of the end moraine, subglacial placers of two kinds may form:

1. Those crossed and covered by the glacier and composed of typical preglacial alluvium concentrations mantled by ground moraine;
2. Those present in subglacial streams, which are usually smaller and of lower grade than the first type due to the more limited amount of detritus and time of stream action.

Meltwater streams form within the end of lateral moraines, reworking the moraines which, when rich in gold (usually derived from bedrock glacial erosion), may supply enough material to create marginal meltwater channel deposits. Rich deposits of this kind are found where the glacier has overridden rich placers for short distances, pushing them as a single unit, without much mixing or dilution.

Below the terminal moraine, outwash streams may reconcentrate gold present in the moraine and in the preglacial alluvium placers unless too much outwash gravel is mixed with it.

The best concentrations of gold during glaciation are those produced during standstill or, better, retreat of glaciers, because the meltwater streams reach the maximum of their reworking capabilities. During a stadial phase, the deposits associated with the farthest advance are more extensive than those associated with later, lesser advances. Each subsequent ice advance may form outwash deposits and the effect may be additive.

IX. Appendix II. Placer platinoids

Previous investigations.

The occurrence, on the bars of the N. Saskatchewan River, of flattened grains of platinum, was first recorded by Hoffman (1891). A sample from the Edmonton area was studied by Hoffman, who found the grains to be maximum 0.25 mm in diameter. About one-fourth of the platinum was magnetic. No iridosmine was present.

Uglow (1920) reported that platinum had been recovered, in small amounts, from the bars and benches of the N. Saskatchewan River, in the vicinity of Edmonton. The same report mentioned that fine grains of platinum, associated with gold, had been found , in small amounts, in the bars and benches of the upper Peace River, mainly between Hudson's Hope and the Ne Parle Pas Rapids.

Certain portions of the gravels were tested by the Canadian Munition Resources Commission, and Mackenzie (1919) published the results of this investigation.

Twenty-two holes were put down with an Empire drill, at Forth Saskatchewan; of these, 18 reached a bedrock (a clay-shale).

The results were summarized as follow:

> "The gold and platinum occur in the form of very small flat flakes or scales rather larger than the fiftieth of an inch in their largest dimentions, and therefore their recovery by dredging operations would be difficult. The gravel which carries the precious metal has an average thickness of about 11 feet, and covering a very large proportion of this gravel is a mantle of fine sand silt with an average thickness of 16 1/2 feet. The flakes of the precious metals were found to lie chiefly in the upper four or five feet of the gravel, and therefore their recovery would require the entire removal of the overlying mantle of silt, which itself is almost quite barren. The samples, with one or two exceptions, were found to contain less than 10 cents in gold and platinum per cubic yard of gravel,[*] and while there are smaller and shallow stretches of the gravel on the river bars which yield values from 12 to 58 cents per cubic yard, the property as a whole was not considered valuable for large scale

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[*] It shoulb be kept in mind that the prices of gold and platinum were, in 1919, 26 $US and 105 $US, respectively.

dredging operations."

Platinoids were also collected by Halferdahl (1965) along the McLeod River, the Milk River, the North Saskatchewan River, the South Saskatchewan River and the Red Deer River (Fig. 62).

Miller (1982, personal communication) studied a few platinum grains obtained from a panned concentrate washed on a gravel bar on the south side of the Groat Bridge within the City of Edmonton, on the inside of a large meander in the river.

Some of the platinoids were strongly magnetic and up to 400 micrometers across. One grain resembled a piece of wire.

One of these grains was composed (in wt.%) by 93.15 % Pt, 3.93 % Fe and about 3.00 % "assumed" Rh (Rhodium was determined by subtraction from 100 %, since no standards were available for probe analysis of this metal, at that time).

Another platinoid grain, obtained from a small, land-based gravel operation at Villneuve, about 20 km from Edmonton, had the following composition (in wt.%): 88 % Pt, 8.69 % Fe and about 3.00 % Rh.

A grain of pure Os-Ir alloy was also observed during the preliminary energy-dispersive scan.

Analysis of native platinum from the North Saskatchewan River.

Electron microprobe analyses (WDA) were performed in the Department of Geology utilizing an ARL-EMX microprobe, on 10 grains. They were all collected from mesh+120. Their morphology was quite variable; their roundness was usually quite high (Plate 34.1) but the sphericity was variable (some were elongated, some approach the shape of a sphere).

The standard used had the following composition:

Pt metal: 100.000 % Pt

Pt-Rh : 71.280 % Pt, 28.720 % Rh

Pt-Fe-Cu: 76.900 % Pt, 14.090 % Fe, 9.010 % Cu

Operating voltage: 15 kV

Counting time on standards: 200 seconds

Counting time on samples: 50 seconds.

The intensities of the following spectral lines of the standards and samples were measured with the indicated analyzing crystals:

Pt M_α - EDDT

Rh L_β - PET

Fe K_α - LIF

Cu K_α - LIF

With the exception of some flat grains, the Corey factor was usually high, from about 0.40 to 0.70 and the equivalent diameter ranged 100-170.

The composition of the grains studied is reported in Table 86. The first five grains (P1 to P5) came from Devon (Locality 24), the others from Locality 28 (Emily Murphy Park, Edmonton).

Intragrain inhomogeneities were minimal (about 0.8 %) whereas intergrain variations reached a maximum of about 2 % for both localities. The following points are noteworthy:

The analyzed platinoids are alloys of Pt, Fe, Cu, and Rh.

A negative correlation was noted between Pt+Fe and Cu+Rh.

X. Appendix III. Gold in coal

Some of the gold found in the concentrates from sand bars along the North Saskatchewan River has the typical features of the gold associated with carbonaceous material elsewere in the world. Many authors have suggested that the coal-bearing Edmonton Formation was the source of the gold in the rivers of Alberta. Tyrrel (1915) found traces of gold in the coal ashes and clinkers resulting from the in situ burning of the coal seam at the top of the Cretaceous Edmonton Formation. This formation forms the banks of the North Saskatchewan Valley.

Pyrite in coal is commonly slightly auriferous, therefore, it could be the source of the gold.

The Coal Seam was sampled at Rocky Mountain House, along the left bank of the river; scales of pyrite were frequently present.

Petrographic studies on this pyrite were not successful in revealing the presence of microscopic forms of gold. If any gold is present it could be bound as an organometallic complex.

A sample weighing 150 gm was ground in a glass mortar (to avoid contaminants, in particular tungsten). From this, two specimens were prepared for neutron activation analysis.

Another sample, 39.746 gm in weight, was ashed at 850 °C for 24 hours. The ash weighed 2.470 gm. 0.507 mg of this were used to prepare 4 specimens for neutron activation analysis.

Gold was not found to be present in significant amounts in the sample analyzed. But, if it is kept in mind that coal outcrops in Alberta are quite common, further studies are strongly recommended in order to have a more complete idea of its content in gold.

XI. Appendix IV. Basic glossary of some placer mining terms

ACCRETION BARS. See - Skim bars.

AINLAY BOWL (KNUDSEN BOWL). It is essentially a bowl with a set of concentric riffles. The rotation of the bowl about its vertical axis and the flow of water cause centrifugal and upward forces to carry out the light minerals, whereas the heavy concentrates are stopped by the riffles.

AMALGAM. An alloy of mercury with gold. Many Hg-Au alloys have been reported, such as Au_2Hg_3, Au_2Hg, $AuHg_2$, Au_3Hg, Au_5Hg. The amalgamation process is a very old method used to recover fine-grained gold. Native gold dissolves in mercury even at room temperature (0.1%) but amalgamation is due to a "wetting effect" produced at the gold surface with significant reduction of surface tension between the two metals. Different kinds of coating or impurities may inhibit the wetting action so that goethite-covered (?) gold ("rusty gold") must be previously cleaned (with nitric acid, for example). Platinum can also be amalgamated, whereas other minerals such as gold-silver tellurides and the light fractions are not wetted by the mercury.

According to Henley (1975) the amalgams formed in the gold recovery process are complex mixtures, not in equilibrium, consisting of a liquid solution of gold in mercury, one or more solid gold-mercury compounds, and solid particles of native gold, coated and cemented together by the other two forms of amalgam.

To increase the affinity for gold and platinum, mercury is sometimes treated with metallic sodium in order to produce "sodium amalgam".

AMALGAMATION. In modern plants the concentrates are ground for many hours in a rotating "barrel" in order to expose clean surfaces of the gold grains. Mercury is then added and the rotation is continued for a few hours. The amalgam is recovered by gravity methods, cleaned by filter-pressing to get rid of most part of the mercury, and the residue is treated with a solution of cyanide to extract the gold.

Plate amalgamation was largely used in the past. It consisted of grinding the ore and forcing the pulp to pass through a copper plate coated with mercury. The gold was then trapped whilst the gangue was discarded.

Mercury has been used in the past and still is utilized at present by prospectors. About half teaspoon of mercury is added to five pounds of concentrates in the pan. Enough water is put in the pan in order to work the mercury through the concentrate. Sooner or later the mercury will gather into a ball which is placed and squeezed (underwater)in a piece of chamois skin or canvas. At this point the gold is still coated with mercury and can be freed by heating the amalgam at least up to 360°C (680°F) since mercury evaporates at 675°F or using the "Baked Potato Method" (that is, hollowing out a small cavity in one of the two halves of a potato, pouring in it the amalgam, reattaching somehow the two parts with a wire, wrapping the potato with aluminum foil and heating for a while in order to vapourize the mercury which will concentrate in the flesh of the potato leaving gold in the cavity). The porous mass of gold remaining after it has been cleaned from the Hg is called "sponge". A "mercury retort" is another device used to separate the mercury and the gold of the amalgam.

See also – Amalgam.

BAJADA (SLOPE) PLACERS. Particular type of desert placers, formed at the base of mountains in alluvial fans sometimes subjected to torrential rain wash.

BATEA. A conical-shaped, wooden dish probably devised by the Mayas and still used in Central and South America and in Asia.
See - Pan.

BENCH PLACERS. Placers located from 50 to several hundred feet above the present streams (Brooks).

BLACK GOLD (OURO PRETO). Gold with a black coating of oxide of manganese, iron oxide or humates of iron. Black gold was found in Brazil in many districts. It was covered with a dark brown to dull black coating of 2 to 25 micrometers in thickness.

A siliceous film is also a frequent type of coating. The general term to define gold with a refractory coating is "rusty gold".

BLACK SAND. Heavy minerals, of dark colour, which are good indicators of gold in placer deposits. The presence of abundant black sand does not necessarily mean that gold is highly concentrated. It (black sand) is usually present in amounts averaging about 35 pounds per yard of gravel [5] (11.67 kgs/tonne or 1.17 wt%) but it may be much more: it vary from 5 to more than 70 pounds per yard of gravel (1.67 kgs/tonne and 23.34 kgs/tonne or 0.17 wt% and 2.33 wt%, respectively). In Western gold placers it ranges between 5 and 20 pounds per cubic yard of bank-run gravel and the typical heavy minerals consist of magnetite, ilmenite, hematite, garnet, zircon, chromite, epidote, olivine, goethite, rutile, pyroxenes, amphiboles, monazite and platinum group metals. In other words, the black sand is a heavy mineral concentrate. When the concentrate contains a lot of magnetite and/or ilmenite, it is more properly called "iron sand".

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[5] Ordinary gravels weights about 3000 pounds per cubic yard.

BULLION. Unrefined, raw gold or silver that has been melted and cast into a bar or ingot or into other shapes, for easy shipping and storage.

BURIED PLACERS. Old placers buried beneath glacial deposits (as in Canada, U.S.S.R.), volcanic material (California, Australia), aeolian deposits (Australia), alluvial material, marine deposits, lacustrine deposits, scree deposits, etc.

CAVITATION. Swirling produced by (natural or artificial) riffles of any dimension on their lower side, which is useful in separating the heavy minerals from the lighter fractions.

COARSE GOLD. Gold is considered to be coarse when it remains on a 10-mesh screen (i.e., grains >2 mm diam.) or when the single grains weigh at least 10 mg or when it is thick enough to be easily picked up with the fingers.

COLLOIDAL GOLD. Ionic or even metallic gold may produce stable colloidal suspensions. The colloids of gold are hydrophobic and have a negative charge, so that they are attracted (absorbed) by hydroxides with a positive charge and easily transported far away. Moreover, colloidal silica, gelatin, etc. act as protectors of gold colloids. They flocculate due to a change in chemical or physical conditions, in particular of pH and Eh.

COLOUR. This term has no exact meaning; it is a term used by miners to refer to a small piece of gold less in size than a nugget, and can vary from 1/16 inch (about 1.5 mm) upward.

CREEK (GULCH) PLACERS. Gravel deposits in the beds and intermediate flood plains of small streams (Brooks).

CROP. Gold deposited on top of river bars after high water.

CYANIDATION. Gold, silver and gold-silver tellurides are soluble in an areated (the presence of oxygen is indispensable for the reaction to occur and must be introduced into the solution) dilute alkaline solution of sodium or potassium cyanide. The dissolution reactions are as follows:

$2Au+4CN^-+O_2+2H_2O \longrightarrow 2Au(CN)_2^-+H_2O_2+2OH^-$

and

$4Au+8CN^-+O_2+2H_2O \longrightarrow 4Au(CN)_2^-+4OH^-$

The first reaction is the most important, the second representing the reaction of dissolution of a smaller portion of material. If the solution is sodium cyanide the reaction equations are, respectively:

$2Au+4NaCN+O_2+2H_2O \longrightarrow 2AuNa(CN)_2+H_2O_2+2NaOH$

and

$4Au+8NaCN+O_2+2H_2O \longrightarrow 4AuNa(CN)_2+4NaOH$

otherwise the cation K substitutes Na in the equations when the potassium cyanide solution is used. The solution is agitated for periods varying between a few hours to a couple of days, depending on particle size, silver content, coatings, degree of liberation of gold particles, percentage of gold-silver tellurides. Carbon dioxide and acid-forming minerals decompose the cyanide, so that lime (0.01% CaO) or caustic soda must be added to maintain the solution to a pH of 10-11. The strength of the solution is typically in the range 0.02–0.08%.

Gold and/or silver ores are amenable to cyanide extraction when the following conditions are present (Clem, 1982):

1. The gold particles must be very small;
2. The ore (if not naturally porous) must be crushed to expose the gold (and silver)- bearing minerals to the action of the cyanide solution;
3. The concentration of "cyanicides" – partially oxidized sulphides of Sb, Zn, Fe, Cu and As – and other interferents inhibiting the solubility of gold and/or silver in the cyanide, must be very low;
4. Carbonaceous material should not be present because it causes absorption of gold or silver cyanide thus causing premature precipitation[6]
5. In order to avoid high lime consumption, the amount of acid-forming minerals must be very low.
6. There should not be an excessive amount of clays or other fines which impede pecolation of the cyanide solution. Agglomeration techniques, for example, may otherwise be necessary to eliminate the problem.

Therefore, the negative effects of various minerals and substances must be avoided or reduced to a large extent. *Stibnite* is one of the main inhibitants of cyanidization; the dissolution of gold and silver is also inhibited by arsenic-bearing minerals (realgar, orpiment, etc.); base metal ions (Fe^{2+}, Fe^{3+}, Zn^{2+}, Cu^{2+}, Ni^{2+}, Mn^{2+}, etc.) are retardants; *copper minerals* are easily dissolved and consume a lot of oxygen and cyanide; *iron sulphides* become oxidized thus producing acid; *arsenopyrite* oxidizes too, but slowly; *organic substances* (grease, oil, flotation reagents, decayed wood, etc.) consume oxygen and therefore retard the reaction.

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[6] According to Henley (1975) various techniques have been tried to avoid the deleterious effect of carbonaceous material, including flotation with depression of the undesidered substances, flotation of carbonaceous matter before the main gold/sulphide flotation step, roasting, oxidation of the carbonaceous matter, etc. Another way of solving the problem was found to be the utilization of the carbon properties, adding coarse activated carbon to the cyanide solution so that gold and silver are absorbed and it is not necessary any more to filter the pulp and precipitate the gold in solution using zinc dust. This has the advantages of reducing equipment costs, of reducing the necessary strength of the soutions, of allowing gold recovering from foul solutions, etc. (Seeton, 1965). Gold and silver are later liberated from the carbon using alkaline sodium sulphide or hot alkaline cyanide solutions. The gold is then recovered by electrolysis (Zadra, 1950; Zadra *et al.*, 1952).

Beside careful mineralogical analysis, some lab tests should be done to determine the suitability of an ore, namely:

1. The bottle-agitation cyanide leach test;
2. The column-percolation leach test;
3. The pilot-scale leach test.

According to Barsky *et al.* (1934) in ideal conditions, the maximum rate of dissolution of pure gold is 3.25 mg/cm^2 /hour corresponding to a penetration of 1.68 microns per hour on each side of a flat gold particle or a total reduction in thickness of 3.36 microns per hour. The authors found also that pure silver dissolves at about half the rate of pure gold, the rates for alloys of the two metals being in proportion of their composition.

DIRT. Miner's term used to describe the material being worked.

DRY PLACERS. Placers in arid or semiarid regions, or generally where surface water is not available. Synonym: desert placers.

ELECTROSTATIC CONCENTRATOR. It consists of a "Frommel" screen which discharges the larger material, and a concentrator box provided with electrostatically charged riffles and a synthetic cloth. Warm air is blown trough the cloth; floating off waste material and creating a static charge on the cloth to attract the fines. So that the fines cling to the cloth before passing into the riffles. Some companies (e.g., Keene Engineering, California) claim that some models have a capacity of up to 2 tons of material per hour and can recover metalliferous particles as fine as 200 mesh.

EXPANDED METAL. Metal screen with diamond-shaped openings (with overhangs). The incline of the mesh must run lengthwise in order to aid the process of "cavitation" which is an important factor when trying to save fine-grained gold. It is usually placed over a carpet in the "false bottom".

FINENESS. Proportion of pure gold in a natural alloy, expressed in parts per thousand.

FLAKE GOLD (Flaky gold). Small chips of gold, usually scales, flattened in placer conditions.

FLOTATION. Technique used to concentrate gold, gold-silver tellurides and sulphides prior to amalgamation, cyanidation, roasting. If the gold is present as free particles, the concentrates obtained from flotation can be directly amalgamated or treated with cyanidation, but quite often part of the gold is hosted by sulphide minerals so that it requires roasting before any other recovery technique is applied. If tarnishing of the sulphides occurred, they must be activated by sulphur dioxide treatment in order to be collected with flotation. Problems also arise when coatings cover the free gold surfaces. After flotation, surface-active reagents (and collectors) may cause problems during cyanidation (gold grains become coated with the collectors and exhibit hydrophobicity) unless roasting (and thence destruction of flotation organic reagents) precedes cyanidation. The first papers dealing with flotation appeared at the beginning of the 20th century (Motherwell, 1914; Lang, 1916) and in 1933 (Fahrenwald) the first report on placer gold flotation was published. Renewed interest on flotation of placer gold followed the rise in the price of gold during the last decade, after 30 years of low interest in this technique. Flotation is based upon the different polarity of the minerals: gold is naturally hydrophobic and its floatability is very high, whereas the other placer minerals usually accompanying the precious metal are highly polar. The typical flaky shape of placer gold increases its floatability which is, by contrast, retarded by the absence of sharp edges on the well rounded placer gold grains.

FLOUR GOLD. Extremely fine-grained gold, defined in the past as finer than 20 mesh and now, due to the improved recovering techniques, finer than 200 mesh, (0.074 mm). Flour gold often floats on water and it runs about 1 to 3 million colors to the ounce. Synonyms: fine (very fine) gold, float gold, flood gold or skim gold. It is not concentrated in placers but usually disseminated as it is easily transported by water. Flour gold can temporarily accumulate in "skim bars". The term *fine gold* also refers to pure gold (1000-fineness).

FREE GOLD. Single gold grains of various size and shape. The term does not include the gold present as inclusions in other minerals of a placer deposit.

FREE GOLD ASSAY. Evaluation of the amount of free gold of a placer, by gravity concentration and amalgamation.

FREE-WASH GRAVEL. Relatively unconsolidated gravel, clay-free.

GOLD DISTRIBUTION. Amount of gold above a unit area of bedrock surface beneath the placer deposit, expressed in cents/sq yd.

GOLD MOMENT. Vertical distribution of gold in placer gravels or position of the "center of gravity" of the gold in a column of gravel; the ratio of distance of the "center of gravity" of gold above bedrock over the total gravel thickness define the gold moment. It is usually expressed as a percentage.

(GOLD) PAN. It is a metal, plastic or wooden dish used to separate precious metals of high specific gravity, washing sand, gravel or other waste. It was developed thousands of years ago. It was very well known in the Middle East where it is depicted on many monuments built 5000 years ago. There are many types of pan:

- *Standard gold pan.* The diameter of the base of a standard 16-inch pan is commonly 9 3/4 to 10 inches and the depth 2.1 inches. It is used in Canada, U.S. and Alaska. The angle between the side and the base is about 141°. Smaller pans are also used, 10, 12, and 14 inches in diameter. The volume of a 16-9 3/4-2 1/2 inch gold pan, when level full, is 332 cubic inches, or 0.007 cubic yard (about 143 pans to a cubic yard). If the swell and weight of sand and gravel is taken into account, a larger number of pans must be allowed to equal a cubic yard (189 to a cubic yard or 7 to a cubic foot). As gravel weighs from 3,000 to 3,400 pounds per yard, a cubic yard is equivalent to over 1 1/2 tons of material. The so-called "riffle pan" is fluted along its side, for about a third of its circumference, with "cheater riffles".
- *Batea:* cone-shaped container, used in Central an Southern America. The standard Brazilian batea is 20 inches in diameter, but can also be 30 to 36 inches across, and 2 1/2 to 3 inches deep. Apical angle: 150°. The volume of, a 20-21 inch batea, when level full is about 262 cubic inches, that is about 0.0056 cubic yards.
- *Dulong:* This can be either a shallow elongate container or similar

to a batea. It is used in the Southeast Asia and India, especially to concentrate cassiterite.

- *Calabash:* A container similar to the dulong or sometimes hemispherical, widely used in Nigeria and the Gold Coast.
- *Perforated pans* are also used as sieves and they are very usefull when panning sand and gravel as it is easy to get rid of unwanted coarse material, thus reducing the time otherwise required for panning.

GRADE. 1. Tenor of an ore. 2. Inclination with respect to a horizontal line of sluices, streams or land surface. A good grade for a sluice-box is around 1 inch per foot, but the optimum may be different, depending upon the water feed, the kind of material worked, the number of boxes and their reciprocal setting (telescopic, arrangement, zig-zag design, etc.). As far as the slope of a river is concerned (usually measured in feet per mile) it seems that a grade of 30 feet per mile favors the formation of a placer, especially when the typical conditions of "mature" stage last for a long time.

GRIZZLY. Screen preventing coarse material from entering the sluice. The "Grizzly" or "Undercurrent" was also an improvement of the typical sluice. It consisted of many identical sluice-boxes set alongside, parallel to the main sluice and with a common feed trough at right angles.

GUTTER. See - Pay streak.

HIDDEN VALUES. The term usually refers to gold which cannot be detected in the black sand, being too fine for the naked eye to be seen.

HILLSIDE PLACERS. A group of gravel deposits intermediate between the creek and bench placers. Their bedrock is slightly above the creek bed, and the surface topography shows no indication of benching. (Brooks)

HYDRAULIC CONCENTRATOR. Device similar to a small sluice-box or to a dredge which has, moreover, the ability to classify the gravel, screening it before it enters into the recovery box. It is usually provided with a pump capable of lifting water up to 200 feet above river level, so that it is particularly useful when operating along the banks of a river. It is able to wash about 1 cubic yard of gravel per hour.

IRON SAND. See - Black sand.

LAKE-BED PLACERS. Placers present at the beds of modern or ancient lakes but they might be drowned stream placers.

LEAD. See - Pay streak.

MINERS' INCH. Unit of water measurement. It used to be the quantity of water flowing through an aperture one inch square through a two inch plank, with a steady flow of water standing 6 inches above the top of the escape aperture. It is different in different places. 1 second-foot is, for example, 40 miners' inches in Oregon, Montana, California and Arizona. In this case 1 miners' inch equals 11.25 gallons/min. (Wells, 1973)

MOSS GOLD. Flour gold trapped by moss or low vegetation on the banks of the river. It accumulates along rivers during high water.

MOSSING (Moss mining). On most surfaces along the banks of gold-bearing streams the gold is easily trapped and accumulated in moss or short vegetation which acts as a sort of Jason's Fleece. After a flood the vegetation can be washed or burned in order to recover the very fine grains of gold it contains.

NUGGET. A grain of native gold or platinum, found in alluvial deposits, whose weight is at least around 1 gram in weight (or 1 pennyweight = 1.5552 grams). Synonym: pepita.

PAY DIRT. Aurifeous gravel where a prospector has found gold enough to pay for working.

PAY STREAK. A miner's term used in Canada and U.S.A. to define the stratum or area of a placer containing an economic concentration of gold. There are many synonyms, such as "pay dirt", "pay wash", "pay gravel", "pay channel", "pay sand", "notch", "gutter", "wash dirt", "gold-bearing channel", "lead" or "pay lead". It is usually a narrow trough in the bedrock.

PLACER. A term used by the early Spanish miners in North and South America to define the gold deposits found in the sands and gravels of streams. Some say it comes from the Spanish word "plaza", meaning a square or from the Spanish word "placer" which means "pleasure". Others claim there was a Spanish-American word, "placer", that meant sand-bank.

PLACER GRAVEL. Rockwaste of a placer deposit which may include fluvial deposits of any size, shape and proportion, till, colluvium, dune sand, mill tailings.

PUDDLING BOX. Wooden box in which the material to be washed was broken and disposed in water and then, after the clay, silt and other light fractions was washed out, the concentrates were panned or shovelled into a rocker.

RETORT. See – Amalgamation.

RIFFLES. Obstructions arranged at the bottom of a sluice, dredge or rocker, made out of stones, wood or metal with the purpose of creating "cavitation" and more effectively disintegrate the material to be washed. There is a wide variety of riffle types: Hungarian r., zig-zag r., block r., pole r., stone r., etc. Natural riffles are also present across the bed of a stream, such as small rapids, waterfalls, sand bars, logs, etc.

ROCKER (Cradle). A box set on curved supports (the rockers, which allow a transverse movement) and with a hopper at the top. The hopper is a removable perforated metal plate (the holes are about 1/4 inch or 1/2 inch diameter) which works as a sort of sieving mesh allowing the coarse material to be discarded. Water is poured into the hopper so that the finer material is washed and trapped in a canvas blanket supported by an inclined frame equipped with riffles. The device is rocked from side to side, by hand, by means of a handle or can be power driven. Advantage: it requires little water. Disadvantage: it is not possible to wash a large volume of material (a few cubic yards per day only).

ROUGH GOLD. Gold with a low degree of roundness, with other minerals attached to it (mainly quartz) which is typical of the reaches close to the primary deposit feeding the placer.

RUSTY GOLD. See - Amalgam. See - Black gold.

SALTING. Placing of gold or other precious mineral in a sample or area to make it appear very rich. Salting can also be accidental, due to careless sampling procedures.

SCALY GOLD. Fine-grained, very flat gold grains. They have a high diameter/thickness ratio.

SECOND-FOOT. A unit of water measurement used to define the flow of rivers. It corresponds to 448.83 gallons/ min. or 1 ft^3/second.

SHOTTY GOLD. Refers to small gold grains, well rounded, almost equidimentional.

SKIM BARS. Also termed "accretion bars" or "point bars". They are bars on the inside of meanders or present in area of sluggish water such as deltas. The term point bar or (skim bar) refers, more precisely to the upper (upstream) end of an accretion bar where flood gold forms superficial concentrations after a flood.

SLICKENS (SLIME). A term used to define the mud discharged as tailings from a placer mine.

SLUICE-BOX. See chapter on field work.
Box sluices: sunk below the surface.
Ground sluices: sunk below the surface.

SNIPER. An individual miner washing gravel with a small sluice-box and/or other simple tools, moving from location to location to pick up preciouos metal pockets which large-scale operations might overlook.

SNIPING. 1. To rework old dumps or claims. 2. To clean out bedrock cracks.

SODIUM AMALGAM. See - Amalgam.

SPONGE. See - Amalgamation.

SUCTION DREDGE. A machine which floats on the surface of the water and dredges gravel from below. It consists of a flotation assembly, a sluice box, a motor and a suction pump with a hose. It eliminates shovelling, it is light and portable, and it allows the prospector to reach and clean-out (snipe)cracks in underwater areas otherwise inaccessible. There are also subsurface dredges. Its use is forbidden in Alberta as the tailings are discharged directly into the river and one can otherwise disrupt the environmental balance of rivers by destroying fish eggs.

SWELL. Increase in volume of gravel or sand when removed from an alluvial deposit. It averages around 25% but can be higher, up to 50%.

TAIL. The wake of heavy minerals (gold, platinum, magnetite, garnets, etc.) left behind when "tailing a pan" (that is, when carefully swirling the water over the concentrates in a gold pan).

TAILINGS. Wastes discarded at the end of any gravity separator (eg., sluice-box). Synonym: dumps, debris.

TOM. Consists of two boxes: the so called "Tom proper" whose lower end (perforated with 1/2 inch holes) rests on the upper end of the second box, which is actually a sort of sluice box with normal riffles. The whole device was about 12 feet long whereas the "Long Tom" was 14-15 feet long.

VANNING. A synonym of panning.

WINNOWING. Old, slow and very inefficient method of separating gold from concentrates practiced in America by the Spanish. They used to place the dried concentrates in a blanket and to fling them into the air, thus getting rid (with the aid of some wind) of the unwanted material, whereas the heavies were supposed to fall back into the blanket.

XII. Appendix V. Geological history of the Interior Plains and their ancient drainage systems

For a better understanding of the possible genesis and the mode of occurrence of gold in Alberta, a description of the geological history of western Canada (with particular reference to the Internal Plains) is necessary, due to the close relationship of orogenies, sequential evolution, glaciations, with provenance, concentration and dispersal of heavy mineral suites. Many excellent papers, mentioned hereafter, have already been published on these topics but none included a study of the opaque minerals, which is an invaluable tool in locating areas of source rocks. Nevertheless, the data and results of these works have been utilized because they provide interesting clues as to the origin of distribution of gold and other heavy minerals in Alberta.

From Jurassic to Paleocene times, detrital material was transported by streams flowing eastward from mountains located to the northwest and southwest of the present Rocky Mountains, and deposited within a subsiding basin. The upper part of the resultant thick sequence of clastic rocks which were derived from this long depositional history, forms the Late Cretaceous-Tertiary bedrock of central Alberta. The Edmonton Formation is the result of accumulation of lenticular bodies of sand, silt, clay and organic material in the western sector of the depositional basin. The eastern portion of the basin was covered by a shallow sea, so that fine-grained material (mainly silty clays) were deposited and diagenized into the shales which are now mostly part of the Bearpaw Formation.

Towards the end of Cretaceous times the shoreline migrated to the east and south and the Paskapoo Formation, mainly continental nonmarine sandstone, conglomerates, lignites, and benthonitic shales, was deposited to the west, thus overlying the Edmonton Formation in Central Alberta.

The upland to the west of the Mowry Sea was apparently rising in Cenomanian-Turonian time (Williams and Stelk, 1975), and unroofing of the

Omineca Batholith is evident in the arkosic nature of the Dunvegan Formation in the Peace River country. A regression towards the east of the interior epeiric sea and a supply of detrital material due to an uplift of the Cordilleran area was reflected by the deposition, in late Turonian times, of the Cardium Fm. A further retreat to the east marked the Campanian and Maestrichtian seas.

> "In Montana and Southern Alberta there is no depositional hiatus, and the Milk River - Eagle delta complexes mark the progradation of the western shore at this time" (Williams and Stelck, 1975).

Large deltaic complexes were present in Alberta due to the accumulation of enormous amounts of detritus supplied by the rising Cordillera.

The last marine transgression penetrated Alberta in Late Campanian - Early Maestrichtian (Bearpaw) times. But the sea retreated again in Maestrichtian times due also to uplift in the Mackenzie Mountains area.

In the western portion of the basin the above mentioned formations are thicker due to the greater rate of subsidence and deposition. Coal seams are present in all these formations but they are more widespread and of better thermal quality in the Edmonton and Paskapoo Formations. Accumulations of organic matter developed preferentially in marshes, lagoons, deltaic areas, when the sea was progressively retreating towards the east.

After the end of the Paleocene, the depositional basin became an area of uplift and erosion due to the Laramide Orogeny which produced the topographic features of the Alberta Plains, which were modified by glaciation in late Pleistocene times. Drift material often filled stretches of preglacial valleys and after the last glacial retreat, which took place about 10,000 years ago, the rivers started to erode again and some of them deepened their valleys enough to reach again the bedrock, cutting the drift covering which had obscured the previous topography. The rivers of Alberta are now flowing in new valleys which intersect and sometimes coincide, for certain stretches, with portions of the buried, wider valleys of the preglacial drainage system. In the Plains of Central Alberta the bedrock is at relatively shallow depths and dips westward at a few feet per mile, so that younger and younger strata outcrop in this direction; whereas the opposite pattern characterizes the Foothills area, due to faulting and folding.

Except for a few irregularities represented by isolated remnants of the "Cypress Plain" and "Flaxville Plain"(Warren, 1939) - the plateaux dissected by the preglacial drainage system - the regional elevation increases from east to west. The Cypress Hills (Southern Alberta) rise about 1,800 feet above the present Plains surface and are capped by gravels of Oligocene age (Russel and Landes, 1940). Also capped with gravels are the Hand Hills, Wintering Hills and probably the Neutral Hills. In Northern Alberta, the Clear Hills, Swan Hills, Cameron Hills, Buffalo Hills, Naylor Hills, Caribou Mountains, Birch Mountains and Mount Watt rise about 1,000 feet from the surrounding land surface (Gravenor and Bayrock, 1961). The old bedrock channels are floored by sands and gravels composed mainly of clasts of quartzite, followed by argillite, limestone, basic volcanics, arkoses, chert and local bedrock material (Rutherford, 1937; Horberg, 1952). Granitic and metamorphic rocks from the Canadian Shield are absent, for these fluvial deposits were laid down prior to glaciation.

Glaciers spread over the Plains moving from two centres:

1. The Kewatin centre (Northwest Territories) and
2. The Cordilleran centre (Rocky Mountains).

The Kewatin glacier moved in a southwesterly direction, thus meeting the Cordilleran glacier, which was at the same time advancing towards east-northeast. Both ice masses flowed subsequently in a southeasterly direction. The resultant glacial drift is about 30 to 100 feet thick over most of the region.

In a study of the heavy, mineral content of till in eastern Alberta, Bayrock (1960) concluded that the heavy minerals make up about 1.7% by weight of the total till and that the bulk of the heavy minerals was derived from the Canadian Shield.

Many clues to understanding the erosional history of the Alberta Plains can be reveled by studying the pattern of the bedrock channels. For instance, the gravel at the top of the Hand Hills does not seem to have been deposited by the Paleo-Red Deer River, but more likely by the Paleo-Bow River, though it now flows south of this area. The Red Deer River is indeed flowing partially in what used to be the preglacial Bow River Valley. The modern and ancient stream channels approximately coincide, or are not very far apart, between Calgary and Bassano. The ancestral river also laid down sand and gravel in areas south of the modern stream bed. In other words, the river valleys were displaced towards the north or south during stadial and interstadial stages and beds of preglacial sand and gravel reveal their original position.

Preglacial valleys are usually broader than the modern ones, being 2 to 10 miles wide, with gently sloping sides and low gradients, due to the long period of erosion which preceded the onset of glaciation. The so called "Saskatchewan sand and gravel" is constantly present above the bedrock, particularly in the western portion of the Plains. Material from the Precambrian Shield to the Northeast is absent. In contrast, post-glacial valleys are relatively narrow, with steeper sides, and their beds contain dark till material laid down during the advance of the first ice mass. Interglacial valleys have intermediate features; material from the Precambrian Shield is present and "Saskatchewan sand and gravel" is very rare.

Since the Oligocene (during which the last uplift of the Rocky Mountains occurred) and before glaciation, degradation prevailed, except for two periods of aggradation in which the stream valleys reached the mature stage. The record of these phases is represented by the above mentioned peneplains, the Cypress Plain and the Flaxville Plain (Warren, 1939).

Some authors suggested that the drainage system was probably integrated and dendritic. This theory is supported by three main factors, namely:

1. The presence of flat-lying shales and soft sandstones in the original stream beds.
2. The tendency of the bedrock channels to occupy broad lowland areas between widely separated rounded uplands.
3. The erosion pattern is likely to have been of the "scarp retreat" kind.

According to Farvolden (1963):

> "If it is assumed that the bedrock topography is of preglacial origin, stream piracy is the most likely explanation for the apparent

downstream bifurcation of several bedrock channels". The bedrock channels show indeed uniformity of gradients, which infers that since preglacial time the land has not been significantly tilted.

The modern valleys have reached in a few cases, and only for short stretches, the depths and grades of their preglacial equivalents (Dawson, 1885). The major rivers typically show a thick alluvium (sometimes 50 feet thick) along their channels so that the modern talweg is well above the original base level. It is likely that certain horizons of sand and gravel are richer in gold than more recent bars and terraces and the gold present in the latter is due to their contribution. The size of the gold from the present day river bars seems to be the same of that from arenaceous phases of ancient channels (Rutherford, 1937).

The gravels from present day river beds consist essentially of limestone, dolomite and quartzite clasts from the local bedrocks; the sands contain material due to disintegration of sandstone, siltstone, shale and coal. The Saskatchewan gravels contributed derived pebbles of quartzite, arkose, etc. As well as these, the above mentioned lithologies from the Canadian Shield are present.

Limestone and dolomite pebbles decrease downstream, whereas there is a concomitant increase in quartzite, granite and gneiss pebbles. Many occurrences of this kind of gravel have been erroneously identified as Saskatchewan sands and gravel. For example the gravel deposits at Ferintosh and Ardley (Rutherford 1937, p. 90) or the gravels in the valley of Kneehills Creek, near the town of Carbon (Fig. 74).

The criterion mentioned above (absence of material which came from the Precambrian Shield) was not always taken into consideration in defining a deposit of gravel and moreover it is the minimum requirement to be verified. Many other situations have to be checked (Stalker, 1968).

The occurrence of the Saskatchewan gravels coincides with the distribution of the bedrock channels, therefore a brief review of the vast literature (Gravenor and Bayrock, 1961; Stalker, 1961 and 1968; Farvolden, 1963; Geiger, 1965; Carlson, 1967; Gabert and Roed, 1968; etc.) on the subject is condensed here.

The North Saskatchewan River follows an ancient bedrock channel from Tp. 47, R. 9, W. 5th Mer. downstream to Tp. 51, R. 3, W. 5th Mer. (Gennessee area). From this point the bedrock channel is displaced further north, passing through Big Lake and the northeastern part of the city of Edmonton. The present river again follows the ancient channel from there to Tp. 58, R. 19, W. 4th Mer. The glacial drift obscures the channel pattern downstream from this point. For certain stretches, the Saskatchewan River flows on ancient tributary bedrock channels in the area SW of Edmonton. These probably join upstream from Devon. A similar arch is formed by the ancient Onoway Bedrock Channel which turns around Wabamun Lake and joins the North Saskatchewan Bedrock Channel at the east end of Big Lake.

The Pembina River flows partially in this channel and in the Dapp Bedrock Channel. Farvolden (1963) suggested two possible hypotheses relative to the origin of this channel: it might be an early stream course abandoned due to stream piracy or it is possibly a channel formed during glaciation.

Two other bedrock channels cross the present-day North Saskatchewan river valley and their trend is approximately parallel to the North Saskatchewan Bedrock Channel. They are the Vegreville Bedrock Channel and the Vermilion Bedrock Channel. They seem to converge in the vicinity of Cold Lake. Their base level was lower than the modern talweg.

Superimposed on these original features are the effects of glaciation cycles. Portions of the bedrock channels were obscured under the drift, but they usually coincide with broad topographic depressions now occupied by streams and lakes. Sometimes, the original bedrock channels were abandoned when covered by drift.

Upstream from Blackfalds the old valley of the Red Deer River coincides approximately with the present channel. From this point it leaves the latter to form an arch which swings eastward (Farvolden, 1963). The bedrock channel passes through Hardisty and continues east through Manito Lake and Reflex Lake. The main tributary channel, the Buffalo Lake Bedrock Channel joins the main channel before Hardisty. Its origin is probably due again to headward erosion and to stream piracy. Preglacial gravel is found on highland near Norway and Camrose at 190 to 325 feet above the base of the immediate preglacial valley. The old valleys are now buried under glacial material, but preglacial gravel and sand have been found near their base.

The paleo-Bow River Channel has an easterly direction and nearly coincides, above Bassano, with the present river valley, but downstream of these points the two channels chose two different directions: the old one seems to follow the Red Deer River in its overall pattern. Many tributaries, joining the main channel from different directions, have also been found. Between Calgary and Bassano, it cuts through 100 to 200 feet of older valley fill: preglacial gravel is the bottom part of it, overlain by till of the first Laurentide glacier. Preglacial gravel terraces, 10 to 12 miles South of Bow River, South of Gleichen, are about 700 feet above the level reached later by the preglacial Bow River, before its course was changed by the first ice-sheet (that was the course of the river 5-8 million years ago).

The Oldman Bedrock Channel follows the present river channel, particularly (upstream from Fort Mac Leod). The Oldman River is now flowing in a valley which was probably the former Milk River Valley which flowed northward to join the Oldman and Bow Rivers.

In conclusion, the term *Saskatchewan Gravels and Sands* refers to that material deposited by the rivers of the region before the glaciers modified the drainage system of the Plains of western Canada. This system was, in preglacial time well-integrated and concentrated into a few large rivers. The rivers had two overall directions of flow, namely: northeastward and eastward.
Tilting in the west and slow uplift of the Plains, forced the rivers to cut deep (200 to 400 feet) valleys which were usually larger (5 to 15 miles wide) than the modern ones as the downcutting was slow and steady. Lateral migration of the ancient rivers resulted in uplands, scattered in various parts of the Plains which today represent remnants of the ancient plateaux.

Stalker (1967) described 3 groups of preglacial gravels and sands, and pointed out that the term *Saskatchewan Gravels and Sands* applies properly only to the third group. The groups are:

1. High level deposits, found only on remnant high areas where they retarded erosion as they form protective caps. These are the oldest gravels.
2. Deposits laid down in intermediate times and at intermediate levels by rivers flowing from the mountains and possibly from high level areas in the Plains.
3. Deposits laid down before the onset of glaciation. They are present at the lowest level of the preglacial valley fill. The first Laurentide glacier marks the end of the deposition of Saskatchewan Gravels and Sands for clasts (granite, gneiss, schist) from the preglacial Shield were included in younger deposits. But the effects were felt progressively westward and southward and not at the same time. Thus the rivers were just slowed down and deposited new material which is usually smaller in size than the previous gravel. Stalker (1967) listed 11 criteria useful for the identification of Saskatchewan Gravel and Sands: eight (one to eight) of them must be satisfied and three (nine to eleven) are corroboratory. Many deposits previously considered preglacial are actually interglacial or interstadial if an accurate analysis is done on the basis of the above mentioned criteria. For example it is improbable that all the three large buried valleys (roughly parallel, striking east-northeastward) in the area near and west of Edmonton are preglacial. Only one is truly preglacial, and it is probably the northernmost, due to the fact that the divertion operated by the glaciers on rivers flowing eastward was not to the north but to the south (Stalker, 1968). Thus some of the data from the literature probably need serious revision.

XIII. Appendix VI. Lithostratigraphy of the Upper Cretaceous-Tertiary and other source rocks

Facies similar to the molasse flanking the Alps are present east of the Rocky Mountains in a sort of homoclinal sequence, dipping about 30 feet per mile towards the west. whereas the topography shows an average slope of 10 feet per mile towards East. The rock are nonmarine in character, Cretaceous to Paleocene in age. The most important formations are: the Porcupine Hill Formation, the Paskapoo Formation and its southeastern and southwestern equivalents (the Ravenscrag and Willow Creek Formations, respectively), the Hand Hills Conglomerate in Central Alberta and the Cypress Hills Formation in Southeastern Alberta. The Rocky Mountains began to emerge about 70 million years ago (Laramian Orogeny) and during the same periods thick coal beds were deposited in Alberta, the dinosaurs became extint and, during a widespread volcanic ashfall, the Kneehills Member (the Battle Formation is its southeastern equivalent) of the Edmonton Formation was laid down in the central Plains. To the West, the strata (Mesozoic and Tertiary in age) were deformed and thrust-faulted.

The Porcupine Hills Formation is composed of crossbedded sandstones and calcareous benthonic shales. Its upper boundary is an erosion surface, the preseved strata reaching a maximum thickness of about 3000 feet. It tapers off in Central Alberta and disappears in the Edmonton Area. There is probably an unconformity between this formation and the underlying Willow Creek and Paskapoo Formations.

The Willow Creek Formation which outcrops in the southwestern Alberta Plains is composed of interbedded benthonitic shales and soft sandstone. In Southeastern Alberta it corresponds to the Ravenscrag Formation, which consists of sandstone and outcrops in the Cypress Hills plateau. The Cypress Hills Formation is a conglomerate capping the Cypress Hills plateau; it ranges from 50 to 100 feet in thickness. There is an unconformity between the Cypress

Hills Formation and the Ravenscrag Formation. The Hand Hills Formation consist of shales, marl and conglomerate beds similar to those of the Cypress Hills Formation. The Paskapoo Formation (Paleocene age) overlies the Edmonton Formation in Central Alberta and also other portions of the province. The lithology is represented by nonmarine sandstones, benthonitic shales, lignites and conglomerates. Its thickness increases from 0 to about 3,000 feet towards the Foothills.

The Edmonton Formation (Late Campanian - Maestrichtian) consists of fresh- and brackish-water, fine-grained sandstones and silty shales, thick coal seams and benthonitic beds. Marine shales represent the transition with the Bearpaw Formation. The thickness averages 1,100-1,700 feet. The best outcrops are along the Saskatchewan River near Edmonton and along the Red Deer Valley in the vicinity of Drumheller.

Ower (1960) distinguished 5 members, namely: A (at the base), B, C, D and E (at the top). Member D corresponds to the tuffs and tuffaceous shale grouped into the Kneehills Member, 20 to 50 feet thick. It is poorly endurated but certain bands are hard due to silicification. C and E are essentially sandstone beds with some intercalations of shales and coal seams. The Ardley coal interval is part of member E.

The Paskapoo Formation is lithologically similar to the Edmonton Formation and there seems to be no clear upper boundary. During Late Cretaceous and Paleocene times the Western Plains were characterized by uninterrupted deposition so there is no unconformity between the two formations.

Interesting data as to the source of the sediments deposited in the Plains during this period have been published by Gallup (1954), Lerbekmo (1963, 1964), Chi (1966), Byers (1969), Shepheard and Hills (1970), Binda (1970), Carrigy (1970, 1971), McLean (1971), Rahmani (1973). Most of the Upper Cretaceous and Paleocene sandstones are greywackes or subgreywackes. The sandstones of the Paskapoo and Ravenscrag Formations are composed of quartz, chert, volcanic and nonvolcanic clasts and minor carbonates. First-cycle grains of euhedral biotite, zircon, epidote, hornblende and apatite characterize the non-opaque heavy mineral assemblages. The Porcupine Hills Formation sandstones are composed of quartz, chert, and carbonate fragments. The heavy mineral assemblage is composed mainly of residual, small, abraded (well rounded) grains of zircon, tourmaline and apatite. The Paskapoo and Ravenscrag Formations show similar paleocurrent directions. The source of the sediments for these formations would be westerly for the former and northwesterly for the latter. The origin of the sediments of the Porcupine Hills Formation would be instead from southwest. The feldspars found in the sandstones were of the albitic variety. Clastic carbonates seem to increase from East to West and from North to South. Micas derived from granites , schists or pyroclastic material were found in the sandstones particularly in the Paskapoo Formation. Epidote and hornblende are absent from the Porcupine Hills sandstones. The Porcupine Hills Formation suite of heavy minerals is composed of resistant, second-cycle, stable heavy-mineral grains, whereas the Paskapoo Formation suite was derived from a volcanic source. The idiomorphic zircons, the biotite and the hornblende may have been derived from pyroclastic material and the rounded zircons are the result of many erosional cycles and are therefore, as far as the period considered is concerned, of sedimentary origin.

Carrigy (1971) postulated, on the basis of the change in composition of the sandstones with time, a shift in the source area from a dominantly volcanic terrain in the interior of B.C. in late Cretaceous and early Paleocene times, to a source area in the Southwest. Montmorillonite is the main authigenic mineral in the Paskapoo sandstone and its presence as a clay mineral in the groundmass of the siltstones in the Porcupine Hills Formation suggested that although the source of coarse-grained, water-transported, volcanic detritus was cut off by the emergence of the Rocky Mountains, volcanic ash continued to fall in substantial quantities during the deposition of the Porcupine Hills Formation sediments. The Porcupine Hills Formation was deposited on a fluviatile floodplain, covered by numerous shallow lakes. The environment of deposition of the Paskapoo is thought to have been an extensive subsiding swampy plain cut by broad drainage channels.

Finally, during Belly River time (Mid-Campanian) the Omineca geanticline which was the result of the Columbian or Nevadan orogeny, supplied coarse clastic material to the depositional basin located to the east and in particular to the Liard-Alberta Trough. Studies conducted on rock fragments and heavy minerals (Lerbekmo, 1963; McLean, 1971; Monger and Hutchison, 1971; Souther, 1972) seem to prove the sedimentary rocks of the Atan Group (Proterozoic-Lower Cambrian) and Cache Creek Group (Upper Paleozoic), the metamorphic rocks of the amphibolite facies exposed in the area of the Omineca geanticline, volcanic material extruded in the Western Cordillera in B.C. and plutonic material from the Nelson batholith, to be the source of the heavy minerals of the Belly River sandstones. Mesozoic plutonic rocks, such as the intrusions of the Cassiar Mountains in the northern part of the Omineca geanticline, were probably unroofed during Mid-Campanian times.

In Edmonton time (Late Middle to Early Late Campanian) the source rocks of the sandstones were probably areas in Northern and Central B.C.: the works of Ritchie (1957), Byers (1969), Binda (1970), Shepheard and Hills (1970), Rahmani (1973), again refer to the Omineca geanticline sedimentary rocks as source of the sandstones' heavy mineral assemblages. An increasing volcanic contribution is postulated. The Kneehills Tuff was probably derived from volcanoes (Late Cretaceous in age) clustering the area of the Boulder Batholith, near Butte, Montana; other volcanic material was supplied also by older Mesozoic volcanics in B.C. An increase in metamorphic rock contributions was also noticed, especially for the upper part of the Edmonton Formation. It was difficult to assess a plutonic supply of material.

In Paskapoo times (Early Lance) the first main pulse of the Laramide orogeny occurred. Heavy and light mineral assemblages show again contributions of sediments from the Cassiar Mountains; the source-rocks were sedimentary, volcanic and metamorphic. Evidence for plutonic supply of material is lacking. An increasing amount of sedimentary material came also from the southwestern part of the ancestral Rocky Mountains of Alberta (Montania?).

The heavy-mineral provinces (Fig. 75) mapped by Rahmani and Lerbekmo are elongated and approximately follow the pattern of the western source areas, that is the Omineca geanticline and the subsequent Laramide Uplift. The investigators suggested the presence of main streams flowing from the Northwest to Southeast, and a drainage system flowing also from Southwest to Northeast, plus the influence of longshore currents in the redistribution of heavy minerals.

XIV. Appendix VII. Tables

TABLE 2. Size-classified gold concentrates. Saskatchewan River, Alberta.

Mesh	Size(mm)	S19	S20	S24	S25	S26	S27	S28	S16	S18	Tot.anal.	Tot.count
+35	>0.5					6					6	20
+60	0.25–0.5	12	11	24	57	67	33		10	31	245	>1000
+120	0.125–0.250			27	17	55	11	47			157	>2000
+230	0.063–0.125			11		23					34	>500
−230(CP)	<0.063											>200
Totals		12	11	62	74	151	44	47	10	31	442	

TABLE 3. Average silver content and standard deviation (SD) of sized gold grains. Saskatchewan River, Alberta.

Mesh	Size(mm)	S19	S20	S24	S25	S26	S27	S28	S16	S18	Av.Wt.%Ag	SD
+35	>0.5					13.1					13.1	6.3
+60	0.25–0.5	11.8	20.4	12.3	12.7	12.2	14.0		14.1	11.0	13.6	6.9
+120	0.125–0.250			15.9	14.0	12.3	21.1	13.3			15.3	8.2
+230	0.063–0.125			19.7		17.5					18.6	9.3
−230(CP)	<0.063											

TABLE 4. Size-classified gold concentrates. Athabasca River, Alberta.

Mesh	Size(mm)	S5	S3	S2	S1	Tot.anal.	Tot.count.
+35	>0.5						1
+60	0.25-0.5						
+120	0.125-0.250				8	8	>50
+230	0.063-0.125	17	13	22	6	58	>100
-230(CP)	<0.063			20		20	>50
Totals		17	13	42	14	86	

TABLE 5. Average silver content and standard deviation (SD) of sized gold grains. Athabasca River, Alberta.

Mesh	Size(mm)	S5	S3	S2	S1	Av.Wt.%Ag	SD
+35	>0.5						
+60	0.25-0.5						
+120	0.125-0.250				10.8	10.8	5.0
+230	0.063-0.125	17.6	17.4	12.7	16.4	16.0	8.7
-230(CP)	<0.063			17.91		17.91	10.1

TABLE 6. Size-classified gold concentrates. Redwater River, Alberta.

Mesh	Size(mm)	S33	Tot.count.
+35	>0.5		
+60	0.25-0.5		
+120	0.125-0.250		
+230	0.063-0.125	12	>200
-230(CP)	<0.063		
Totals		12	

TABLE 7. Average silver content and standard deviation (SD) of sized gold grains. Redwater River, Alberta.

Mesh	Size(mm)	S33	Av.Wt.%Ag	SD
+35	>0.5			
+60	0.25-0.5			
+120	0.125-0.250			
+230	0.063-0.125	14.1	14.1	6.7
-230(CP)	<0.063			

TABLE 8. Size-classified gold concentrates. Vermilion River, Alberta.

Mesh	Size(mm)	S35	Tot.count.
+35	>0.5		
+60	0.25-0.5		
+120	0.125-0.250	13	>50
+230	0.063-0.125		
-230(CP)	<0.063		
Totals		13	

TABLE 9. Average silver content and standard deviation (SD) of sized gold grains. Vermilion River, Alberta.

Mesh	Size(mm)	S35	Av.Wt.%Ag	SD
+35	>0.5			
+60	0.25-0.5			
+120	0.125-0.250	11.4	11.4	7.7
+230	0.063-0.125			
-230(CP)	<0.063			

TABLE 10. Electron probe analyses of native gold from Locality 1; average wt%. Mesh 120.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	86.10	96.30	13.74	2.96	0.30	0.75
2	86.01	95.77	13.86	2.79	0.14	1.45
3	91.85	95.41	7.88	3.66	0.28	0.29
4	91.58	96.81	8.08	2.84	0.35	0.36
5	91.03	96.61	8.78	2.95	0.20	0.44
6	93.51	96.24	5.89	3.62	0.61	0.14
7	93.36	95.87	6.20	3.88	0.45	0.25
8	77.72	93.69	21.89	5.81	0.39	0.50

TABLE 11. Electron probe analyses of native gold from Locality 1; ranges (wt%). Mesh 120.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	85.57-86.43	96.04-96.55	13.40-14.18	2.88-3.03	0.15-0.51	0.57-0.97
2	85.43-86.36	95.65-95.88	13.46-14.42	2.68-2.90	0.00-0.31	1.44-1.45
3	91.73-92.00	94.55-96.66	7.61-8.18	3.00-4.67	0.09-0.39	0.26-2.31
4	91.06-91.91	96.50-97.00	7.74-8.56	2.79-2.85	0.30-0.38	0.15-0.70
5	90.91-91.14	96.20-96.87	8.71-8.84	2.88-3.07	0.15-0.25	0.24-0.73
6	92.79-94.65	95.84-96.72	3.95-6.76	3.01-4.03	0.36-1.39	0.03-0.27
7	92.96-93.82	94.91-96.83	5.84-6.66	3.08-4.68	0.23-0.82	0.09-0.41
8	77.41-78.05	93.24-94.35	21.64-22.12	5.21-6.33	0.00-0.95	0.42-0.78

TABLE 12. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 1. Mesh 120.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	6.27	32.53	0.160	0.031	862.38	970.18	0.302	300
2	6.21	34.33	0.161	0.029	861.22	971.69	0.380	403
3	11.66	26.07	0.086	0.038	920.99	963.06	0.128	180
4	11.33	34.09	0.088	0.029	918.92	971.50	0.215	241
5	10.37	32.75	0.097	0.031	912.03	970.37	0.230	235
6	15.88	26.59	0.063	0.038	940.74	963.75	0.251	237
7	15.06	24.71	0.066	0.041	937.73	961.10	0.400	210
8	3.55	16.13	0.282	0.062	780.24	941.61	0.120	199

TABLE 13. Electron probe analyses of native gold from Locality 1; average wt%. Mesh 230.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	87.19	95.52	12.79	4.48	0.01	0.00
2	91.00	96.10	9.00	3.90	0.00	0.00
3	66.50	95.01	33.45	4.94	0.04	0.05
4	91.21	94.82	8.77	5.18	0.02	0.00
5	75.40	97.10	24.58	2.89	0.02	0.01
6	90.00	94.33	10.00	5.67	0.00	0.00

TABLE 14. Electron probe analyses of native gold from Locality 1; ranges (wt%). Mesh 230.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	87.02-87.31	95.40-95.64	12.65-12.95	4.36-4.61	0.00-0.15	
2	90.89-91.14	96.02-96.22	8.86-9.11	3.87-3.98	-	
3	66.34-66.71	94.92-95.12	33.17-33.64	4.80-5.07	0.00-0.12	0.00-0.09
4	91.14-91.33	94.70-94.94	8.59-8.84	5.06-5.30	0.00-0.08	
5	75.27-75.51	96.98-97.22	24.42-24.70	2.76-3.00	0.00-0.07	0.00-0.03
6	89.97-90.04	94.26-94.51	9.96-10.03	5.49-5.72	-	

TABLE 15. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 1, Mesh 230.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	6.82	21.32	0.147	0.047	892.08	955.20	0.370	109
2	10.11	24.64	0.099	0.041	910.00	961.00	0.403	118
3	1.99	19.23	0.503	0.052	665.33	950.06	0.450	120
4	10.40	18.31	0.096	0.055	912.28	948.20	0.398	106
5	3.07	33.60	0.326	0.030	754.15	971.10	0.280	138
6	9.00	16.64	0.111	0.060	900.00	943.30	0.375	104

TABLE 16. Electron probe analyses of native gold from Locality 2; average wt%. Mesh 230.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	92.90	96.15	7.10	3.85	0.00	0.01
2	88.36	96.09	11.64	3.88	0.00	0.03
3	87.10	96.00	12.90	3.99	0.00	0.01
4	85.43	96.30	14.57	3.68	0.00	0.02
5	91.00	97.15	9.00	2.86	0.00	0.01
6	93.00	97.40	7.00	2.60	0.00	0.00
7	88.10	96.20	11.90	3.79	0.00	0.01
8	89.12	96.01	10.87	3.95	0.01	0.01
9	90.44	96.51	9.56	3.48	0.01	0.02
10	90.91	96.00	9.09	4.00	0.00	0.01
11	91.20	95.99	8.80	4.01	0.00	0.00
12	91.10	96.30	8.89	3.70	0.01	0.00
13	86.70	95.33	13.30	4.67	0.00	0.00
14	86.90	95.49	13.10	4.51	0.00	0.00
15	85.91	96.08	14.09	3.92	0.00	0.01
16	87.77	96.14	12.23	3.25	0.00	0.01
17	90.00	94.91	10.00	5.09	0.00	0.00
18	88.18	96.55	11.82	3.43	0.00	0.02

19	88.70	96.09	11.30	3.90	0.00	0.01
20	86.69	96.00	13.31	4.00	0.00	0.00
21	62.40	96.09	37.54	3.91	0.05	0.00
22	78.20	96.30	21.80	3.67	0.00	0.03

TABLE 17. Electron probe analyses of native gold from Locality 2; ranges (wt%). Mesh 230.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	91.81-93.99	96.07-96.22	6.01-8.19	3.76-3.93	–	0.00-0.02
2	88.34-88.38	95.04-96.96	11.62-11.66	3.04-4.94	–	0.00-0.14
3	87.01-87.34	95.98-96.40	11.50-12.98	3.62-4.28	–	0.00-0.12
4	84.02-86.82	96.00-97.02	13.17-15.98	2.92-4.00	–	0.00-0.09
5	90.02-91.40	96.02-97.51	8.60-9.98	2.48-3.98	–	0.00-0.10
6	91.33-93.54	97.10-97.54	6.46-8.67	2.46-2.90	–	
7	88.05-88.17	96.07-96.31	11.81-11.94	3.66-3.90	–	0.00-0.03
8	89.00-89.15	95.90-96.08	10.82-11.00	3.92-4.09	0.00-0.02	0.00-0.03
9	90.32-90.51	96.40-96.57	9.48-9.68	3.30-3.55	0.00-0.02	0.00-0.09
10	90.88-90.93	95.98-96.02	9.07-9.12	3.98-4.02	–	0.00-0.10
11	91.17-91.23	95.97-96.01	8.77-8.83	3.99-4.03	–	
12	91.08-91.12	96.25-96.33	8.87-8.92	3.67-3.92	0.00-0.02	
13	86.66-86.72	95.30-95.37	13.34-13.28	4.63-4.70	–	
14	86.87-86.92	95.43-95.51	13.08-13.13	4.49-4.57	–	–
15	85.89-86.94	96.05-96.11	14.11-13.04	3.95-3.89	–	0.00-0.12
16	87.74-87.80	96.10-96.17	12.20-12.26	3.80-3.90	–	0.00-0.05
17	89.97-90.03	94.89-94.95	9.97-10.03	5.05-5.11	–	

18	88.15-88.20	96.52-96.58	11.75-11.85	3.38-3.48	-	0.00-0.08
19	88.67-88.72	96.05-96.12	11.28-11.33	3.87-3.90	-	0.00-0.09
20	86.67-86.72	95.99-96.02	13.28-13.33	3.98-4.01	-	
21	62.36-62.45	95.48-96.12	37.45-37.60	3.88-4.52	0.00-0.12	
22	78.04-78.25	95.49-96.39	21.74-21.96	3.58-4.51	-	0.00-0.07

TABLE 18. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 2. Mesh 230.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam
1	13.08	24.97	0.076	0.040	929.00	961.50	0.338	115
2	7.59	24.77	0.132	0.040	883.60	961.19	0.566	140
3	6.75	24.06	0.148	0.042	871.00	960.10	0.294	140
4	5.86	26.17	0.171	0.038	854.30	963.19	0.530	115
5	10.11	33.97	0.099	0.029	910.00	971.40	0.459	129
6	13.29	37.46	0.075	0.027	930.00	974.00	0.455	126
7	7.40	25.38	0.135	0.039	881.00	962.10	0.320	118
8	8.20	24.31	0.122	0.041	891.29	960.50	0.291	140
9	9.46	27.73	0.106	0.036	904.40	965.20	0.433	121
10	10.00	24.00	0.100	0.040	909.10	960.00	0.419	130
11	10.36	23.94	0.097	0.042	912.00	959.90	0.412	121
12	10.25	26.03	0.098	0.038	911.09	963.00	0.388	113
13	6.52	20.41	0.153	0.049	867.00	953.30	0.237	150
14	6.63	21.17	0.151	0.047	869.00	954.90	0.381	141
15	6.10	24.51	0.164	0.041	859.10	960.70	0.281	140

16	7.18	24.97	0.139	0.040	877.70	961.50	0.403	120
17	9.00	18.65	0.111	0.054	900.00	949.10	0.391	114
18	7.46	28.15	0.134	0.036	881.80	965.69	0.400	115
19	7.85	24.64	0.127	0.041	887.00	961.00	0.299	123
20	6.51	24.00	0.154	0.042	866.90	960.00	0.318	140
21	1.66	24.57	0.602	0.041	624.37	960.90	0.457	125
22	5.39	26.24	0.279	0.381	782.00	963.29	0.255	142

TABLE 19. Electron probe analyses of native gold from Locality 2; average wt%. Mesh CP.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	85.09	94.01	14.88	5.97	0.02	0.02
2	78.15	96.54	21.85	3.41	0.00	0.05
3	86.51	94.38	13.48	5.61	0.02	0.02
4	61.47	0.00	38.48	0.00	0.05	0.00
5	90.85	0.00	9.09	0.00	0.06	0.00
6	87.99	0.00	11.97	0.00	0.03	0.00
7	89.49	95.43	10.51	4.52	0.01	0.06
8	62.20	91.00	37.79	8.93	0.01	0.08
9	90.08	95.05	9.90	4.95	0.03	0.00
10	91.10	94.40	8.85	5.60	0.06	0.00
11	79.40	93.80	20.60	6.19	0.00	0.03
12	85.81	95.33	14.18	4.66	0.01	0.01
13	62.00	*	38.00	*	0.01	0.00
14	88.20	95.54	11.78	4.46	0.03	0.00
15	93.20	96.18	6.76	3.82	0.05	0.00
16	87.18	93.91	12.80	6.09	0.02	0.00
17	90.18	95.20	9.77	4.80	0.05	0.00

18	77.15	97.20	22.85	2.80	0.00	0.01
19	79.00	95.80	20.98	4.20	0.02	0.00
20	76.20	96.28	23.74	3.71	0.06	0.01

TABLE 20. Electron probe analyses of native gold from Locality 2; ranges (wt%). Mesh CP.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	82.46-86.69	93.48-94.81	13.31-17.47	5.19-6.47	0.00-0.07	0.00-0.10
2	77.69-78.93	96.27-96.68	21.07-22.31	3.23-3.59	-	0.00-0.14
3	86.39-86.59	94.33-94.42	13.40-13.54	5.58-5.67	0.00-0.08	
4	60.30-65.57	*	34.40-39.21	*	0.00-0.12	*
5	90.35-91.72	*	8.28-9.52	*	0.00-0.18	*
6	86.73-89.07	*	10.93-13.17	*	0.00-0.09	*
7	88.82-91.19	93.04-96.54	8.81-11.16	3.31-6.96	0.00-0.02	0.00-0.14
8	62.15-62.23	90.95-91.03	37.72-37.82	9.05-8.90	0.00-0.17	
9	90.02-90.13	95.00-95.09	9.93-9.79	5.00-4.91	0.00-0.15	
10	91.03-91.13	94.35-94.46	8.80-8.90	5.54-5.65	0.00-0.10	
11	79.36-79.44	93.77-93.83	20.64-20.56	6.23-6.07	-	0.00-0.10
12	85.79-85.84	95.30-95.35	14.10-14.21	4.63-4.70	0.00-0.09	
13	61.97-62.04	*	37.10-38.04	*	0.00-0.18	*
14	88.18-88.23	95.50-95.60	11.70-11.81	4.40-4.51	0.00-0.14	0.00-0.02
15	93.17-93.24	96.14-96.25	6.72-6.80	3.75-3.86	0.00-0.12	
16	87.12-87.24	93.81-93.98	12.72-12.83	6.01-6.12	0.00-0.02	0.00-0.01
17	90.09-90.23	95.15-95.23	9.72-9.80	4.77-4.85	0.00-0.03	

18	77.10-77.19	97.12-97.24	22.81-22.88	2.76-2.83	0.00-0.02	0.00-0.13
19	78.97-79.03	95.77-95.84	20.94-21.00	4.17-4.22	0.00-0.08	0.00-0.03
20	76.13-76.24	96.24-96.31	23.70-23.87	3.68-3.73	-	0.00-0.10

TABLE 21. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 2. Mesh CP.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam
1	5.72	15.75	0.175	0.063	851.16	940.29	0.180	78
2	3.58	28.31	0.279	0.035	781.50	965.88	0.578	67
3	6.42	16.82	0.156	0.060	865.19	943.89	0.290	58
4	1.60	*	0.625	*	615.01	*	0.195	56
5	9.99	*	0.100	*	909.05	*	0.256	62
6	7.35	*	0.136	*	880.25	*	0.230	66
7	8.51	21.11	0.118	0.047	894.90	954.87	0.771	80
8	1.65	10.19	0.606	0.098	622.06	910.64	0.253	61
9	9.10	19.20	0.110	0.052	900.98	950.50	0.200	59
10	10.29	16.86	0.097	0.059	911.46	944.00	0.308	74
11	3.85	15.15	0.260	0.066	794.00	938.09	0.190	78
12	6.05	20.46	0.165	0.049	858.19	953.40	0.241	66
13	1.63	*	0.614	*	620.00	*	0.521	78
14	7.49	21.42	0.134	0.047	882.18	955.40	0.551	80
15	13.79	25.18	0.073	0.040	932.37	961.80	0.288	77

16	6.81	15.42	0.147	0.065	871.97	939.10	0.210	55
17	9.23	19.83	0.108	0.050	902.25	952.00	0.221	53
18	3.38	34.71	0.296	0.029	771.50	972.00	0.255	61
19	3.77	22.81	0.265	0.044	790.16	958.00	0.540	68
20	3.21	25.95	0.312	0.039	762.46	962.90	0.215	67

TABLE 22. Electron probe analyses of native gold from Locality 3; average wt%. Mesh 230.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	87.20	95.50	12.78	4.50	0.02	0.00
2	65.15	94.81	34.83	5.13	0.02	0.06
3	76.20	96.10	23.70	3.89	0.10	0.01
4	77.80	97.15	22.18	2.84	0.02	0.01
5	88.88	95.40	11.09	4.60	0.03	0.00
6	90.23	95.16	9.74	4.84	0.03	0.00
7	91.10	97.10	8.90	2.90	0.00	0.00
8	85.29	94.06	14.69	5.94	0.02	0.00
9	86.04	95.30	13.96	4.70	0.00	0.00
10	90.10	95.00	9.90	5.00	0.00	0.00
11	62.40	92.75	37.57	7.19	0.03	0.06
12	87.44	94.00	12.54	6.00	0.02	0.00
13	85.90	96.05	14.10	3.95	0.00	0.00

TABLE 23. Electron probe analyses of native gold from Locality 3; ranges (wt%). Mesh 230.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	87.15-87.36	95.10-95.71	12.62-12.84	4.25-4.85	0.00-0.17	-
2	65.00-65.29	94.62-94.98	34.67-35.00	5.00-5.29	0.00-0.05	0.00-0.10
3	76.08-76.25	96.02-96.15	23.58-23.81	3.82-3.95	0.00-0.14	0.00-0.03
4	77.73-77.85	97.02-97.23	22.10-22.24	2.79-2.93	0.00-0.07	0.00-0.03
5	88.78-88.94	95.29-95.63	11.02-11.18	4.51-4.70	0.00-0.08	-
6	90.15-90.40	95.00-95.21	9.64-9.89	4.76-4.92	0.00-0.09	
7	91.02-91.15	97.01-97.33	8.79-8.99	2.75-3.15	-	
8	85.19-85.41	93.98-94.26	14.50-14.81	5.86-6.01	0.00-0.04	
9	85.89-86.18	95.14-95.44	13.88-14.10	4.55-4.84	-	-
10	90.01-90.13	94.89-95.13	9.78-10.03	4.91-5.17	-	
11	62.28-62.51	92.63-92.84	37.09-37.70	7.04-7.30	0.00-0.12	0.00-0.10
12	87.37-87.52	93.95-94.17	12.33-12.70	5.89-6.15	0.00-0.05	
13	85.80-86.04	95.89-96.16	14.02-14.15	3.88-3.99	-	

TABLE 24. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 3. Mesh 230.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	6.82	21.25	0.147	0.047	872.17	955.00	0.092	92
2	1.87	18.48	0.535	0.054	651.63	948.67	0.108	71
3	3.22	24.70	0.311	0.040	762.76	961.10	0.124	90
4	3.51	34.21	0.285	0.029	778.16	971.60	0.193	112
5	8.01	20.74	0.125	0.048	889.07	954.00	0.089	74
6	9.26	19.66	0.108	0.051	902.57	951.60	0.297	112
7	10.24	33.48	0.098	0.030	911.00	971.00	0.099	75
8	5.81	15.84	0.172	0.063	853.07	940.60	0.144	63
9	6.16	20.28	0.162	0.049	860.40	953.00	0.155	103
10	9.10	19.00	0.110	0.053	901.00	950.00	0.062	79
11	1.66	12.90	0.602	0.078	624.19	928.06	0.456	105
12	6.97	15.67	0.143	0.064	874.57	940.00	0.208	106
13	6.09	24.32	0.164	0.041	859.00	960.50	0.283	86

TABLE 25. Electron probe analyses of native gold from Locality 5; average wt%. Mesh 230.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	88.37	95.79	11.62	4.19	0.01	0.02
2	87.40	94.32	12.59	5.65	0.01	0.03
3	88.80	95.04	11.20	4.96	0.01	0.02
4	90.20	94.40	9.79	5.60	0.01	0.00
5	91.44	95.10	8.52	4.89	0.03	0.01
6	72.28	92.44	27.70	7.55	0.01	0.02
7	68.19	93.10	31.79	6.86	0.03	0.04
8	85.17	91.91	14.82	8.09	0.01	0.00
9	63.55	91.10	36.45	8.89	0.01	0.01
10	90.10	95.44	9.90	4.56	0.00	0.00
11	87.08	94.51	12.90	5.49	0.02	0.00
12	88.83	95.62	11.09	4.36	0.06	0.02
13	78.20	96.55	21.80	3.45	0.00	0.00
14	92.44	94.66	7.56	5.34	0.00	0.00
15	77.58	90.58	22.37	9.40	0.05	0.02
16	62.33	92.22	37.66	7.76	0.01	0.02
17	89.18	94.78	10.81	5.19	0.02	0.03

TABLE 26. Electron probe analyses of native gold from Locality 5; ranges (wt%). Mesh 230.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	86.18-90.36	95.25-96.12	9.21-13.87	3.88-4.70	0.00-0.05	0.00-0.05
2	85.40-88.20	93.02-95.14	10.12-13.00	4.13-5.77	0.00-0.06	
3	86.20-89.01	94.44-95.20	10.99-13.80	4.80-5.56	0.00-0.04	0.00-0.05
4	90.10-90.38	94.21-94.63	9.58-9.89	5.35-5.70	0.00-0.05	
5	91.27-91.53	95.02-95.22	8.47-8.71	4.73-4.96	0.00-0.07	0.00-0.02
6	72.10-72.37	92.12-92.58	27.60-27.85	7.40-7.87	0.00-0.04	0.00-0.03
7	68.00-68.27	93.01-93.19	31.38-31.92	6.80-6.95	0.00-0.08	0.00-0.07
8	85.03-85.29	91.77-92.04	14.72-14.97	7.96-8.23	0.00-0.03	
9	63.40-63.65	91.03-91.23	36.35-36.60	8.75-8.96	0.00-0.03	0.00-0.02
10	90.05-90.017	95.09-95.88	9.83-9.95	4.12-4.91	-	
11	86.91-87.23	94.11-94.86	12.75-13.09	5.14-5.89	0.00-0.04	
12	88.72-88.94	95.44-95.80	11.06-11.15	4.15-4.52	0.00-0.17	0.00-0.05
13	78.06-78.29	96.14-96.70	21.71-21.94	3.30-3.86	-	
14	92.23-92.61	94.50-94.78	7.39-7.77	5.22-5.50	-	
15	77.49-77.63	90.45-90.66	22.28-22.51	9.34-953	0.00-0.09	0.00-0.03
16	62.20-62.44	92.08-92.43	37.56-37.81	7.53-7.91	0.00-0.03	0.00-0.04
17	89.04-89.27	94.53-94.91	10.71-10.97	5.07-5.46	0.00-0.05	0.00-0.04

TABLE 27. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 5. Mesh 230.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	7.60	22.86	0.132	0.044	883.79	958.09	0.208	106
2	6.94	16.69	0.144	0.060	874.09	943.48	0.215	104
3	7.93	19.16	0.126	0.052	888.00	950.40	0.241	98
4	9.21	16.86	0.109	0.059	902.09	944.00	0.280	84
5	10.73	19.45	0.093	0.051	914.77	951.10	0.310	78
6	2.60	12.24	0.383	0.082	722.94	924.49	0.200	112
7	2.15	13.57	0.466	0.074	682.04	931.37	0.209	108
8	5.75	11.36	0.174	0.088	851.79	919.10	0.195	115
9	1.74	10.25	0.574	0.098	635.50	911.09	0.177	131
10	9.10	20.93	0.110	0.048	901.00	954.40	0.159	133
11	6.75	17.21	0.148	0.058	870.97	945.10	0.288	89
12	8.01	21.93	0.125	0.046	889.01	956.39	0.301	73
13	3.59	27.99	0.279	0.036	782.00	965.50	0.344	79
14	12.23	17.73	0.082	0.056	924.40	946.60	0.202	104
15	3.47	9.64	0.288	0.104	776.19	905.98	0.190	107

16	1.66	11.88	0.604	0.084	623.36	922.38	0.215	108
17	8.25	18.26	0.121	0.055	891.89	948.08	0.180	129

TABLE 28. Electron probe analyses of native gold from Locality 16; average wt%. Mesh 60.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	83.68	95.21	16.33	4.80	0.00	0.00
2	85.86	96.77	14.12	3.23	0.02	0.00
3	93.57	96.91	6.37	3.04	0.06	0.05
4	70.69	94.53	29.31	5.45	0.00	0.01
5	90.34	96.91	9.65	3.07	0.01	0.01
6	75.45	93.10	24.53	8.63	0.01	0.01
7	81.92	92.29	18.05	7.70	0.02	0.01
8	92.72	97.04	7.23	2.95	0.05	0.01
9	92.74	96.91	7.23	3.09	0.03	0.01
10	91.90	95.93	8.06	4.05	0.04	0.02

TABLE 29. Electron probe analyses of native gold from Locality 16; ranges (wt%). Mesh 60.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	72.82-88.89	91.42-96.91	11.11-27.18	3.09-8.58	0.00-0.01	-
2	85.78-85.96	96.49-97.21	14.04-14.22	2.79-3.51	0.00-0.13	-
3	93.19-94.02	96.84-96.96	5.98-6.76	3.02-3.07	0.00-0.12	0.00-0.14
4	69.20-75.50	93.28-95.32	24.50-30.80	4.68-6.68	0.00-0.01	0.00-0.03
5	89.92-90.72	96.66-97.17	9.28-10.08	2.77-3.34	0.00-0.04	0.00-0.06
6	73.60-79.39	87.37-97.01	20.61-26.40	2.99-12.63	0.00-0.07	0.00-0.02
7	81.19-82.57	85.74-97.07	17.43-18.71	2.93-14.26	0.00-0.12	0.00-0.04
8	92.58-92.89	96.64-97.37	7.06-7.35	2.62-3.36	0.00-0.10	0.00-0.03
9	92.51-92.99	96.43-97.25	6.93-7.49	2.75-3.52	0.00-0.11	0.00-0.06
10	91.52-92.12	93.10-97.16	7.87-8.48	2.84-6.90	0.00-0.30	0.00-0.12

TABLE 30. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 16. Mesh 60.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	5.12	19.84	0.195	0.050	836.72	952.00	0.095	536
2	6.08	29.96	0.164	0.033	858.77	967.70	0.126	410
3	14.69	31.88	0.068	0.031	936.26	969.58	0.122	413
4	2.41	17.34	0.415	0.058	706.90	945.49	0.191	525
5	9.36	31.57	0.107	0.032	903.49	969.29	0.225	603
6	3.08	10.79	0.325	0.093	754.65	915.17	0.151	438
7	4.54	11.99	0.220	0.083	819.45	922.99	0.234	523
8	12.82	32.89	0.078	0.030	927.66	970.50	0.114	402
9	12.83	31.36	0.078	0.032	927.68	969.10	0.135	382
10	11.40	23.69	0.088	0.042	919.37	959.49	0.117	481

TABLE 31. Electron probe analyses of native gold from Locality 18; average wt%. Mesh 60.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	92.27	*	7.73	*	0.00	*
2	85.09	96.09	14.83	3.88	0.08	0.04
3	88.65	96.20	11.35	3.47	0.01	0.33
4	92.30	94.03	7.64	5.98	0.06	0.00
5	86.42	96.85	13.46	3.08	0.11	0.07
6	89.25	96.76	10.75	3.14	0.00	0.10
7	80.53	95.85	19.47	4.16	0.00	0.00
8	91.95	*	7.91	*	0.13	*
9	92.68	93.41	7.32	6.59	0.00	0.00
10	88.31	95.90	11.69	4.10	0.00	0.00
11	91.66	96.83	8.34	3.17	0.00	0.00
12	82.09	96.40	17.88	3.60	0.03	0.00
13	91.01	96.75	5.99	3.21	0.00	0.03
14	92.92	96.76	7.00	3.18	0.09	0.06
15	87.33	*	12.66	*	0.02	*
16	76.65	94.97	23.35	5.03	0.00	0.00
17	94.86	96.57	5.15	3.42	0.00	0.01
18	94.80	*	5.20	*	0.00	*

19	91.34	*	8.66	*	0.00	*
20	91.58	95.83	8.42	4.17	0.00	0.00
21	74.69	89.25	25.31	10.69	0.01	0.06
22	89.28	96.93	10.70	3.01	0.02	0.06
23	77.08	96.64	22.89	3.33	0.03	0.04
24	91.03	96.77	8.88	3.12	0.03	0.12
25	88.41	96.76	11.53	3.08	0.07	0.16
26	94.84	96.20	5.16	3.01	0.00	0.81
27	90.04	96.74	9.91	3.17	0.04	0.09
28	95.47	96.49	4.41	3.29	0.13	0.21
29	90.64	96.88	9.31	3.77	0.05	0.02
30	90.13	96.43	9.87	3.33	0.00	0.25
31	92.38	96.80	7.50	3.02	0.13	0.18

TABLE 32. Electron probe analyses of native gold from Locality 18; ranges (wt%). Mesh 60.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	91.83-92.76	*	7.22-8.17	*	0.00-0.02	*
2	84.72-85.36	95.32-96.91	14.62-15.15	3.09-4.60	0.02-0.13	0.00-0.09
3	88.54-88.81	94.23-97.10	11.19-11.46	2.43-5.66	0.00-0.03	0.00-0.71
4	92.10-92.39	93.95-94.10	7.49-7.74	5.90-6.05	0.00-0.24	–
5	84.90-89.72	96.66-97.01	10.28-15.07	2.91-3.20	0.00-0.45	0.00-0.14
6	88.62-89.69	96.37-97.18	10.30-11.38	2.76-3.36	0.00-0.01	0.00-0.35
7	80.46-80.57	93.18-96.77	19.43-19.54	3.23-6.82	–	–
8	91.62-92.56	*	7.44-8.28	*	0.00-0.31	*
9	92.43-92.98	93.23-93.58	7.02-7.57	6.42-6.77	–	–
10	88.07-88.66	93.33-96.88	11.34-11.93	3.13-6.67	–	–
11	91.56-91.82	96.61-97.03	8.18-8.44	2.97-3.38	–	
12	81.85-82.54	95.76-96.79	17.46-18.11	3.21-4.24	0.00-0.08	
13	93.70-94.25	96.70-96.79	5.75-6.30	3.20-3.21	–	0.00-0.10
14	92.79-93.04	96.63-96.95	6.85-7.14	2.86-3.37	0.07-0.11	0.00-0.19
15	87.06-87.65	*	12.34-12.94	*	0.00-0.05	*
16	75.97-77.01	93.72-96.96	22.09-24.03	3.04-6.28	–	–
17	94.82-94.89	96.83-97.02	5.11-5.18	2.98-4.17	–	0.00-0.02

18	94.59-94.92	*	5.08-5.41	*	-	*
19	91.15-91.77	*	8.23-8.85	*	-	*
20	90.98-92.17	95.23-96.79	7.83-9.02	3.21-4.77	-	
21	74.32-74.96	86.42-91.57	25.04-25.64	8.43-13.41	0.00-0.04	0.00-0.17
22	88.34-90.98	96.82-97.14	9.02-11.57	2.74-3.12	0.00-0.09	0.00-0.12
23	76.59-77.38	96.54-96.75	22.62-23.31	3.25-3.38	0.00-0.10	0.00-0.11
24	90.63-91.38	96.53-96.92	8.50-9.37	2.93-3.33	0.00-0.11	0.07-0.15
25	87.56-89.63	96.28-97.02	10.36-12.39	2.87-3.39	0.01-0.13	0.00-0.33
26	94.68-95.15	96.17-96.22	4.85-5.32	3.00-3.01	-	0.77-0.84
27	89.13-90.73	96.21-97.18	9.13-10.87	2.82-3.60	0.00-0.13	0.00-0.19
28	95.14-95.73	96.32-96.72	4.21-4.56	3.04-3.62	0.00-0.30	0.05-0.52
29	90.33-90.95	94.84-96.95	9.00-9.67	3.00-5.16	0.00-0.20	0.00-0.05
30	89.75-90.40	96.18-96.67	9.60-10.25	2.95-3.70	-	0.12-0.37
31	92.16-92.53	96.60-96.92	7.25-7.75	2.80-3.40	0.07-0.22	0.00-0.32

TABLE 33. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 18. Mesh 60.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	11.94	*	0.084	*	922.70	*	0.055	325
2	5.74	24.77	0.174	0.040	851.58	961.19	0.083	327
3	7.81	27.72	0.128	0.036	886.50	965.19	0.064	349
4	12.08	15.83	0.083	0.063	942.41	939.36	0.084	272
5	6.42	31.44	0.156	0.032	865.24	969.18	0.119	349
6	8.30	30.82	0.120	0.033	892.50	967.60	0.113	319
7	4.14	23.04	0.242	0.043	805.30	958.50	0.099	335
8	11.62	*	0.086	*	920.79	*	0.090	309
9	12.66	14.17	0.079	0.071	926.80	934.10	0.148	356
10	7.55	23.39	0.132	0.043	883.10	959.00	0.291	461
11	10.99	30.55	0.091	0.033	916.60	968.30	0.136	343
12	4.59	26.78	0.218	0.037	821.15	964.00	0.081	351
13	15.69	30.14	0.064	0.033	940.10	967.89	0.155	353
14	13.27	30.43	0.075	0.033	929.94	968.18	0.167	287
15	6.90	*	0.145	*	873.39	*	0.139	315

16	3.28	18.88	0.305	0.053	766.50	949.70	0.081	438
17	18.42	28.24	0.054	0.035	947.65	965.80	0.243	420
18	18.23	*	0.055	*	948.00	*	0.124	309
19	10.55	*	0.095	*	913.40	*	0.146	424
20	10.88	22.98	0.092	0.044	915.80	958.30	0.183	469
21	2.95	8.35	0.339	0.120	746.90	893.04	0.112	455
22	8.34	32.20	0.120	0.031	892.98	969.88	0.169	491
23	3.37	29.02	0.297	0.035	771.03	966.69	0.141	512
24	10.25	31.02	0.098	0.032	911.12	968.77	0.070	358
25	7.67	31.42	0.130	0.032	884.63	969.15	0.090	365
26	18.38	31.96	0.054	0.031	948.40	969.76	0.081	366
27	9.09	30.52	0.110	0.033	900.85	968.27	0.191	422
28	21.65	29.33	0.046	0.034	955.85	967.03	0.102	376
29	9.74	25.70	0.103	0.039	906.85	962.54	0.074	289
30	9.13	28.96	0.110	0.035	901.30	966.62	0.139	282
31	12.32	32.05	0.081	0.031	924.91	969.75	0.146	251

TABLE 34. Electron probe analyses of native gold from Locality 19; average wt%. Mesh 60.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	86.17	87.77	13.83	12.23	0.00	0.00
2	89.60	96.27	10.40	3.73	0.01	0.00
3	92.43	93.96	7.33	6.04	0.04	0.00
4	92.51	93.58	7.47	6.42	0.02	0.00
5	73.95	77.51	26.05	22.48	0.00	0.01
6	82.02	96.10	17.98	3.73	0.01	0.00
7A	92.05	95.17	7.95	4.83	0.05	0.00
7B	86.71	96.33	13.29	3.67	0.00	0.00
7C	86.80	96.32	13.15	3.69	0.00	0.00
8	95.34	96.30	4.16	3.70	0.00	0.00
9	91.73	91.82	8.27	8.18	0.00	0.00
10	88.09	96.40	11.89	3.60	0.03	0.00

TABLE 35. Electron probe analyses of native gold from Locality 19; ranges (wt%). Mesh 60.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	85.91-86.67	85.77-96.22	13.33-14.09	3.78-14.23	–	–
2	89.31-90.32	95.73-96.49	9.68-10.69	3.51-4.27	0.00-0.03	–
3	92.30-93.41	92.46-96.46	6.48-7.70	3.54-7.54	0.00-0.11	–
4	92.12-92.98	92.12-96.52	7.02-7.88	3.48-7.88	0.00-0.06	
5	73.71-74.37	72.07-92.44	25.63-26.29	7.56-27.90	–	0.00-0.02
6	81.72-82.32	95.39-96.37	17.68-18.28	3.63-4.61	0.00-0.08	–
7A	91.97-92.33	94.37-96.63	7.67-8.32	3.37-5.63	0.01-0.10	
7B	86.48-86.86	95.99-96.67	13.14-13.43	3.33-4.01	–	–
7C	86.70-87.28	96.31-96.32	12.72-13.30	3.68-3.69	–	–
8	94.82-96.61	96.07-96.43	3.39-5.18	3.57-3.93	–	
9	91.40-91.92	91.59-92.03	8.08-8.58	7.97-8.41	–	
10	87.89-88.39	96.19-96.74	11.61-12.04	3.26-3.81	0.00-0.07	

TABLE 38. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 19. Mesh 60.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	6.23	7.18	0.161	0.139	861.70	877.70	0.196	471
2	8.62	25.81	0.116	0.039	896.00	962.70	0.171	362
3	12.61	15.56	0.079	0.064	926.52	939.60	0.150	571
4	12.38	14.58	0.081	0.069	925.29	935.80	0.183	577
5	2.84	3.45	0.352	0.290	739.50	775.18	0.202	505
6	4.56	25.76	0.219	0.039	820.20	962.64	0.245	640
7A	11.58	19.70	0.086	0.051	920.50	951.70	0.174	576
7B	6.52	26.25	0.153	0.038	867.10	963.30	"	"
7C	6.60	26.10	0.152	0.038	868.43	963.10	"	"
8	22.92	26.03	0.044	0.038	958.19	963.00	0.187	494
9	11.09	11.23	0.090	0.089	917.30	918.20	0.503	726
10	7.41	26.78	0.135	0.037	881.08	964.00	0.478	933

TABLE 37. Electron probe analyses of native gold from Locality 20; average wt%. Mesh 60.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	79.86	95.88	20.10	4.12	0.04	0.00
2	84.52	86.61	14.46	13.81	0.02	0.00
3	89.87	96.06	10.13	3.95	0.04	0.00
4	87.64	96.45	12.36	3.55	0.01	0.00
5A	86.51	92.71	13.29	7.29	0.00	0.00
5B	85.55	91.56	14.30	8.31	0.13	0.00
5C	69.40	90.70	30.60	9.30	0.00	0.00
5D	67.98	92.40	32.02	7.60	0.00	0.00
6	66.58	96.19	33.40	3.81	0.02	0.00
7	89.77	96.59	10.18	3.42	0.05	0.00
8	66.93	95.68	33.01	4.32	0.07	0.00

TABLE 38. Electron probe analyses of native gold from Locality 20; ranges (wt%). Mesh 60.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	79.61-79.97	95.73-96.17	19.87-20.34	3.83-4.27	0.00-0.16	-
2	84.33-84.68	84.10-93.96	15.32-15.67	6.04-15.90	0.00-0.06	-
3	89.55-89.99	95.40-96.73	10.01-10.45	3.27-4.60	0.00-0.22	-
4	87.27-87.91	96.34-96.56	12.09-12.73	3.44-3.66	0.00-0.03	
5A	86.44-86.84	92.46-92.96	13.16-13.56	7.04-7.54	-	-
5B	84.80-85.92	91.52-91.60	14.02-14.48	8.40-8.48	0.00-0.32	-
5C	69.10-69.57	90.20-91.00	30.43-30.90	9.00-9.80		
5D	67.88-68.12	91.52-93.43	31.88-32.12	6.57-8.48	-	-
6	66.00-67.10	95.44-96.52	32.82-33.98	3.48-4.56	0.00-0.08	-
7	89.74-90.34	96.20-96.97	9.66-10.50	3.03-3.80	0.00-0.13	
8	66.75-67.10	94.06-96.45	32.76-33.25	3.55-5.94	0.00-0.13	

TABLE 39. Au/Ag, Ag/Au ratios, fineness, Corey shape factor an equivalent diameter of individual gold grains from Locality 20. Mes 60.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	3.97	23.27	0.252	0.043	798.92	958.80	0.234	532
2	5.85	6.27	0.171	0.159	853.91	862.48	0.306	546
3	8.87	24.32	0.113	0.041	898.70	960.50	0.114	264
4	7.09	27.17	0.141	0.037	867.40	964.50	0.112	300
5A	6.51	12.72	0.154	0.079	866.83	927.10	0.075	342
5B	5.98	11.02	0.167	0.091	856.78	916.79	"	"
5C	2.27	9.75	0.441	0.103	694.00	907.00	"	"
5D	2.12	12.16	0.472	0.082	679.80	924.00	"	"
6	1.99	25.25	0.503	0.040	665.93	961.90	0.188	416
7	8.82	28.24	0.113	0.035	898.15	965.80	0.081	378
8	2.03	22.15	0.493	0.045	669.70	956.80	0.184	306

TABLE 40. Electron probe analyses of native gold from Locality 24; average wt%. Mesh 60.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	74.03	96.32	25.97	3.68	0.00	0.00
2	86.08	95.93	13.92	4.07	0.00	0.00
3	92.18	91.59	7.82	8.41	0.00	0.00
4	90.87	94.68	8.79	5.32	0.00	0.00
5	89.97	94.95	10.03	5.05	0.00	0.00
6	75.50	96.11	24.50	3.89	0.00	0.00
7	88.79	96.56	11.21	3.44	0.00	0.00
8	75.85	78.56	23.93	21.09	0.22	0.36
9	92.34	95.14	7.66	4.86	0.00	0.00
10	93.32	95.36	6.68	4.64	0.00	0.00
11	90.63	90.95	9.37	9.05	0.00	0.00
12	80.28	95.80	19.72	4.32	0.00	0.00
13	91.04	96.16	8.96	3.84	0.00	0.00
14	84.46	*	15.54	*	0.00	*
15	91.27	96.42	8.73	3.58	0.00	0.00
16	92.68	95.79	7.39	4.21	0.00	0.00
17	93.28	95.64	6.73	4.36	0.00	0.00
18	82.25	89.74	17.75	10.27	0.00	0.00

19A	89.81	90.08	10.19	9.92	0.00	0.00
19B	89.55	96.04	10.45	3.96	0.00	0.00
20	94.73	95.60	5.28	4.40	0.00	0.00
21	74.70	*	25.30	*	0.00	*
22	92.22	96.44	7.78	3.56	0.00	0.00
23	78.75	88.75	21.25	11.25	0.00	0.00

TABLE 41. Electron probe analyses of native gold from Locality 24; ranges (wt%). Mesh 60.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	73.99-74.06	96.29-96.35	25.94-26.01	3.65-3.71	–	–
2	86.01-86.12	95.47-96.28	13.88-13.99	3.78-4.53	–	–
3	91.89-92.66	91.54-91.64	7.34-8.11	8.36-8.46	–	–
4	90.44-91.47	94.28-95.04	8.29-9.56	4.96-5.72	–	–
5	89.51-90.68	93.64-96.28	9.32-10.49	3.72-6.36	–	–
6	75.20-75.70	95.97-96.51	24.30-24.80	3.49-4.43	–	–
7	88.55-89.01	96.42-96.74	10.99-11.45	3.26-3.58	–	–
8	75.75-76.01	77.28-79.84	23.60-24.20	20.16-22.01	0.00-0.65	0.00-0.71
9	92.32-92.36	94.13-95.67	7.64-7.68	4.33-5.87	–	–
10	93.19-93.42	95.27-95.53	6.58-6.81	4.47-4.73	–	–
11	90.02-90.68	90.76-91.10	9.32-9.98	8.90-9.24	–	–
12	80.15-80.41	95.52-96.24	19.85-19.59	3.76-4.48	–	–
13	90.18-92.34	95.73-96.44	7.66-9.82	3.56-4.27	–	–
14	84.36-84.57	*	15.64-15.43	*	–	–
15	91.14-91.43	96.25-96.67	8.57-8.86	3.33-3.75	–	–
16	92.48-92.99	95.62-96.01	7.01-7.52	3.99-4.38	–	–
17	92.91-93.24	95.45-95.83	6.17-7.09	4.17-4.55	–	–

18	80.61-84.76	89.72-89.75	15.24-19.39	10.25-10.28	-	-
19A	89.80-89.82	89.88-90.33	10.18-10.20	9.67-10.11	-	-
19B	89.40-89.75	96.00-96.12	10.25-10.60	3.88-4.00	-	-
20	94.67-94.78	94.61-96.28	5.22-5.33	3.72-5.59	-	-
21	74.23-75.47	*	24.53-25.77	*	-	-
22	91.59-92.64	96.25-96.56	7.36-8.41	3.44-3.75	-	
23	77.51-80.62	88.59-88.91	19.38-22.49	11.09-11.41	-	

TABLE 42. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 24. Mesh 60.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam
1	2.85	26.17	0.351	0.038	740.30	963.20	0.062	355
2	6.18	23.57	0.162	0.042	860.80	959.30	0.063	289
3	11.79	10.89	0.085	0.092	921.80	915.90	0.103	441
4	10.34	17.80	0.097	0.056	911.80	946.80	0.051	271
5	8.97	18.80	0.111	0.053	899.70	949.50	0.116	517
6	3.08	24.71	0.325	0.040	755.00	961.10	0.101	451
7	7.92	28.07	0.126	0.036	887.90	965.60	0.103	406
8	3.17	3.72	0.315	0.269	760.17	788.36	0.104	393
9	12.05	19.58	0.083	0.051	923.40	951.40	0.043	447
10	13.97	20.55	0.072	0.049	933.20	953.60	0.066	404
11	9.67	10.05	0.103	0.100	906.30	909.50	0.121	365
12	4.07	22.18	0.246	0.045	802.80	956.85	0.095	464
13	10.16	25.04	0.098	0.040	910.40	961.60	0.072	507
14	5.44	*	0.184	*	844.60	*	0.058	281
15	10.45	26.93	0.096	0.037	912.70	964.20	0.108	491

16	12.66	22.75	0.079	0.044	926.80	957.90	0.091	240
17	13.86	21.94	0.072	0.046	932.71	956.40	0.065	207
18	4.63	8.74	0.216	0.114	822.50	897.31	0.099	493
19A	8.81	9.08	0.114	0.110	898.10	900.80	0.358	639
19B	8.57	24.25	0.117	0.041	895.50	960.40	*	*
20	17.94	21.73	0.056	0.046	947.20	956.00	0.144	347
21	2.95	*	0.339	*	747.00	*	0.188	371
22	11.85	27.09	0.084	0.037	922.20	964.40	0.191	374
23	3.71	7.89	0.270	0.127	787.50	887.50	0.101	366

TABLE 43. Electron probe analyses of native gold from Locality 24; average wt%. Mesh 120.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1A	94.66	95.91	5.34	4.06	0.00	0.03
1B	88.79	92.36	11.21	7.63	0.00	0.00
2	91.35	96.06	8.65	3.94	0.00	0.00
3A	86.46	93.63	13.54	6.37	0.01	0.00
3B	92.47	95.30	7.51	4.69	0.02	0.01
4	83.07	94.08	16.93	5.89	0.00	0.03
5	69.93	94.85	30.08	5.15	0.00	0.00
6	86.17	92.45	13.82	7.55	0.00	0.00
7	71.43	96.73	28.54	3.27	0.03	0.00
8	70.10	88.74	29.89	11.21	0.01	0.05
9A	75.82	*	24.18	*	0.00	*
9B	85.95	92.80	14.05	7.20	0.00	0.00
9C	88.94	96.50	11.06	3.50	0.00	0.00
9D	91.87	95.42	8.11	4.58	0.03	0.00
10	86.05	95.78	13.94	4.22	0.01	0.00
11	84.15	*	15.85	*	0.00	*
12	93.00	*	6.98	*	0.02	*

13A	76.76	93.50	23.25	6.50	0.00	0.00
13B	95.90	*	4.10	*	0.00	*
13C	71.38	80.64	28.62	19.36	0.00	0.00
13D	96.44	*	3.56	*	0.00	*
14	68.68	89.95	31.32	10.03	0.00	0.02
15	90.85	*	9.09	*	0.06	*
16	61.68	*	38.26	*	0.06	*
17	94.01	*	5.97	*	0.02	*
18	79.23	86.41	20.76	13.59	0.02	0.00
19	96.53	*	3.40	*	0.07	*

TABLE 44. Electron probe analyses of native gold from Locality 24; ranges (wt%). Mesh 120.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1A	94.62-94.70	95.40-96.53	5.30-5.38	3.47-4.60	-	0.00-0.13
1B	88.42-89.21	89.99-95.71	10.79-11.58	3.29-10.01	-	0.00-0.01
2	90.29-92.00	95.88-96.27	8.00-9.71	3.73-4.12	0.00-0.03	0.00-0.01
3A	85.99-86.92	93.01-94.57	13.08-14.00	5.43-6.96	0.00-0.01	-
3B	90.17-93.34	94.79-95.70	6.66-9.83	4.27-5.21	0.00-0.07	0.00-0.04
4	81.75-84.90	92.66-96.45	15.10-18.25	3.45-7.34	-	0.00-0.10
5	69.37-70.48	92.77-96.87	29.52-30.63	3.13-7.23	-	-
6	80.09-89.64	92.14-93.25	10.36-19.91	6.75-7.86	-	-
7	71.28-71.68	96.51-97.01	28.32-28.72	2.99-3.49	0.00-0.13	-
8	68.68-74.00	86.47-90.90	25.96-31.32	8.83-13.53	0.00-0.04	0.00-0.27
9A	75.35-76.72	75.35-76.72	23.28-24.65	23.28-24.65	-	-
9B	85.62-86.19	90.00-96.59	13.81-14.38	3.41-10.00	-	-
9C	88.89-88.99	96.37-96.66	11.01-11.11	3.34-3.63	-	-
9D	91.13-92.52	94.47-96.54	7.48-8.82	3.46-5.53	0.00-0.08	-
10	84.17-87.86	94.89-96.31	11.43-15.79	3.69-5.11	0.00-0.04	-
11	83.25-84.64	*	15.36-16.75	*	-	*
12	92.57-93.24	*	6.76-7.43	*	0.00-0.14	*

13A	76.25–77.26	92.47–94.53	22.71–23.75	5.47–7.53	–	
13B	95.55–96.78	*	3.22–4.45	*	–	*
13C	65.45–74.74	80.32–81.02	25.26–34.55	18.98–19.68	–	
13D	95.78–96.83	*	3.17–4.22	*	–	*
14	64.03–73.30	86.73–95.82	26.70–35.97	4.18–13.17	–	0.00–0.09
15	90.35–91.72	–	8.28–9.52	–	0.00–0.18	
16	60.34–64.51	*	35.49–39.57	*	0.00–0.16	*
17	93.48–94.81	*	5.19–6.47	*	0.00–0.10	*
18	77.69–82.46	86.13–86.69	17.47–22.31	13.31–13.87	0.00–0.07	
19	96.27–96.68	*	3.23–3.59	*	0.00–0.14	*

TABLE 45. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 24. Mesh 120.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam
1A	17.73	23.62	0.056	0.042	946.60	959.39	0.135	165
1B	7.92	12.10	0.126	0.083	887.90	923.69	0.108	164
2	10.56	24.38	0.095	0.041	913.50	960.60	0.885	251
3A	6.39	14.70	0.156	0.068	864.60	936.30	0.130	97
3B	12.31	20.32	0.081	0.049	924.89	953.10	0.162	104
4	4.91	15.97	0.204	0.063	830.70	941.08	0.160	110
5	2.32	18.42	0.431	0.054	966.23	948.50	0.641	155
6	6.24	12.25	0.160	0.082	861.79	924.50	0.850	179
7	2.50	29.58	0.400	0.034	714.51	967.30	0.333	109
8	2.35	7.92	0.426	0.126	701.07	887.84	0.241	87
9A	3.14	*	0.318	*	758.20	*	0.166	168
9B	6.12	12.89	0.163	0.078	859.50	928.00	*	*
9C	8.04	27.57	0.124	0.036	889.40	965.00	0.244	223
9D	11.33	20.83	0.088	0.048	918.88	954.20	*	*
10	6.17	22.70	0.162	0.044	860.59	957.80	0.199	138

11	5.31	*	0.188	*	841.50	*	0.410	247
12	13.32	*	0.075	*	930.19	*	0.236	220
13A	3.30	14.38	0.303	0.070	767.52	935.00	0.566	230
13B	23.39	*	0.043	*	959.00	*	"	"24
13C	2.49	4.17	0.402	0.240	713.80	806.40	"	"
13D	27.93	*	0.036	*	964.40	*	"	"
14	2.19	8.97	0.457	0.111	686.80	899.68	0.496	178
15	9.99	*	0.100	*	909.05	*	0.623	153
16	1.61	*	0.621	*	617.17	*	0.256	114
17	15.75	*	0.063	*	940.29	*	0.216	172
18	3.82	6.36	0.262	0.157	792.38	864.10	0.239	166
19	28.39	*	0.035	*	965.98	*	0.485	185

TABLE 46. Electron probe analyses of native gold from Locality 24; average wt%. Mesh 230.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	68.23	78.21	31.76	21.73	0.01	0.06
2	67.70	83.99	32.26	15.97	0.05	0.04
3	66.18	86.57	33.79	13.39	0.03	0.04
4	87.93	92.10	12.07	7.86	0.00	0.04
5	91.25	93.74	8.74	6.26	0.02	0.01
6	92.54	*	7.45	*	0.01	*
7	69.04	84.60	30.95	15.28	0.01	0.12
8	85.07	90.41	14.90	9.51	0.03	0.08
9	82.11	86.79	17.88	13.20	0.01	0.02
10	86.22	95.65	13.70	4.33	0.08	0.02
11	86.36	96.23	13.64	3.72	0.00	0.05

TABLE 47. Electron probe analyses of native gold from Locality 24; ranges (wt%). Mesh 230.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	68.00-69.09	74.67-80.53	30.91-31.93	19.47-25.30	0.00-0.06	0.00-0.14
2	64.82-73.93	80.40-88.52	26.07-35.13	11.48-19.58	0.00-0.16	0.00-0.20
3	65.83-66.91	81.55-88.89	33.09-34.05	10.97-18.45	0.00-0.16	0.00-0.14
4	87.60-88.26	91.02-93.41	11.74-12.40	6.59-8.83	-	0.00-0.15
5	89.75-91.88	93.07-94.86	8.12-10.22	5.11-6.93	0.00-0.08	0.00-0.04
6	91.99-94.30	*	5.67-8.01	*	0.00-0.11	*
7	67.95-71.34	84.39-85.01	28.66-32.05	14.99-15.47	0.00-0.09	0.00-0.24
8	84.65-85.27	90.02-91.04	14.73-15.35	8.86-9.85	0.00-0.12	0.00-0.13
9	80.37-83.99	85.13-88.45	16.01-19.63	11.54-14 .86	0.00-0.05	0.01-0.02
10	85.63-86.66	95.30-95.85	13.31-14.27	4.12-4.70	0.03-0.13	0.00-0.04
11	85.61-88.04	95.85-96.61	11.96-14.39	3.31-4.12	-	0.03-0.07

TABLE 48. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 24. Mesh 230.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	2.15	3.60	0.465	0.278	682.37	782.57	0.149	128
2	2.10	5.26	0.476	0.190	677.27	840.24	0.340	125
3	1.96	6.47	0.510	0.155	622.00	866.05	0.188	121
4	7.29	11.72	0.137	0.085	879.30	921.37	0.280	81
5	10.44	14.97	0.096	0.067	912.59	937.40	0.148	124
6	12.42	*	0.081	*	925.49	*	0.155	129
7	2.23	5.54	0.448	0.181	690.47	847.02	0.157	124
8	5.71	9.51	0.175	0.105	850.96	904.82	0.130	145
9	4.59	6.58	0.218	0.152	821.18	867.99	0.169	122
10	6.29	22.09	0.159	0.045	862.89	956.69	0.131	135
11	6.33	25.87	0.158	0.039	863.60	962.78	0.229	126

TABLE 49. Electron probe analyses of native gold from locality 25; average wt%. Mesh 60.

Grain no.	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	91.70	96.76	8.27	3.25	0.04	0.00
2	81.28	96.86	18.72	3.13	0.00	0.00
3	93.03	*	6.96	*	0.01	*
4	74.18	96.10	25.81	3.77	0.01	0.14
5	78.54	84.22	21.47	15.79	0.00	0.00
6	89.53	90.80	10.40	9.17	0.08	0.03
7	83.44	95.16	16.56	4.77	0.00	0.07
8	83.00	96.44	17.00	3.56	0.00	0.00
9	92.23	95.60	7.78	4.40	0.00	0.00
10	94.01	96.74	6.00	3.27	0.00	0.00
11	78.66	95.76	21.46	4.24	0.00	0.00
12	92.85	95.48	7.16	4.29	0.00	0.23
13	71.04	92.08	28.96	7.92	0.00	0.00
14	92.36	*	7.61	*	0.02	*
15	92.09	96.79	7.82	3.22	0.05	0.00
16	92.20	97.12	7.81	2.88	0.00	0.00
17	92.89	*	7.11	*	0.00	*

18	92.88	95.70	7.09	4.31	0.03	0.00
19	92.30	*	7.59	*	0.11	*
20	87.19	*	12.81	*	0.00	*
21	84.40	96.43	15.60	3.19	0.00	0.38
22	93.77	96.12	6.18	3.75	0.06	0.14
23	93.30	*	6.66	*	0.04	*
24	82.90	94.73	17.92	5.23	0.00	0.05
25	86.50	96.86	13.50	3.12	0.00	0.01
26	78.49	97.15	21.51	2.85	0.00	0.00
27	93.63	*	6.37	*	0.00	0.00
28	93.86	*	6.14	*	0.00	0.00
29	88.44	95.66	11.56	4.29	0.00	0.05
30	79.37	96.59	20.64	3.25	0.00	0.16
31	92.20	*	7.66	*	0.14	*
32	74.39	96.74	25.61	3.24	0.00	0.02
33	93.63	96.37	6.37	3.19	0.00	0.44
34	92.39	96.75	7.62	2.91	0.00	0.35
35	81.35	96.37	18.65	3.63	0.00	0.00
36	92.40	97.16	7.60	2.85	0.00	0.00
37	80.18	87.45	19.83	12.57	0.00	0.00

38	77.44	96.96	22.57	3.05	0.00	0.00
39	82.32	96.35	17.68	3.65	0.00	0.00
40	89.56	95.35	10.45	4.46	0.00	0.20
41	85.65	*	14.24	*	0.12	*
42	77.05	96.60	22.84	3.41	0.11	0.00
43	95.27	96.49	4.74	3.36	0.00	0.14
44	87.06	91.66	12.94	8.34	0.00	0.00
45	92.94	*	7.06	*	0.00	*
46	87.08	*	12.92	*	0.00	*
47	88.56	*	11.44	*	0.00	*
48	93.56	*	6.44	*	0.00	*
49	92.58	*	7.14	*	0.11	*
50	94.99	96.52	5.00	3.38	0.11	0.00
51	87.73	95.52	12.28	4.48	0.00	0.00
52	78.23	93.85	21.70	6.15	0.07	0.00
53	82.38	96.36	17.63	3.65	0.00	0.00
54	93.61	95.11	6.33	4.84	0.07	0.05
55	85.13	94.41	14.85	5.55	0.03	0.05
56	89.82	94.85	10.16	5.15	0.02	0.00
57	90.74	95.16	9.25	4.84	0.01	0.00

TABLE 50. Electron probe analyses of native gold from Locality 25; ranges (wt%). Mesh 60.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	91.50-91.90	96.70-96.81	8.06-8.47	3.19-3.30	0.03-0.04	-
2	80.69-81.65	96.82-96.90	18.35-19.31	3.09-3.17	-	-
3	93.00-93.06	*	6.94-6.98	*	0.00-0.02	*
4	74.15-74.21	95.78-96.42	25.79-25.83	3.40-4.13	0.00-0.02	0.09-0.18
5	78.19-78.88	83.23-85.20	21.12-21.81	14.80-16.77	-	-
6	89.43-89.62	90.10-91.50	10.23-10.57	8.44-9.90	0.00-0.15	0.00-0.06
7	83.22-83.68	92.48-96.84	16.32-16.78	3.16-7.32	-	0.00-0.21
8	82.50-83.49	95.94-96.94	16.51-17.50	3.06-4.06	-	-
9	92.05-92.50	95.47-95.72	7.60-7.95	4.28-4.53	-	-
10	93.52-94.49	96.32-97.15	5.51-6.48	2.85-3.68	-	-
11	78.38-79.01	93.80-96.84	20.99-21.62	3.16-6.20	-	-
12	92.51-93.18	94.03-96.55	6.82-7.49	3.08-5.97	-	0.00-1.05
13	69.47-73.79	91.36-92.80	26.21-30.53	7.20-8.64	-	-
14	91.36-92.88	*	7.01-8.64	*	0.00-0.12	*
15	90.61-93.77	96.55-97.02	5.98-9.39	2.98-3.45	0.00-0.25	-
16	90.83-93.56	97.03-97.21	6.44-9.17	2.79-2.97	-	-
17	92.14-93.80	*	6.20-7.86	*	-	*

18	91.76-93.56	95.31-96.06	6.44-8.16	3.92-4.69	0.00-0.09	
19	91.71-93.61	*	6.23-8.09	*	0.00-0.28	*
20	85.89-88.50	*	11.50-14.11	*	-	*
21	84.05-84.74	96.35-96.50	15.26-15.96	3.15-3.23	-	0.35-0.41
22	93.76-93.77	96.05-96.18	6.13-6.23	3.70-3.80	0.00-0.11	0.12-0.16
23	92.37-93.77	*	6.13-7.63	*	0.00-0.11	*
24	82.02-82.15	92.68-97.22	17.85-17.98	2.78-7.32	-	0.00-0.18
25	86.36-86.72	96.74-96.93	13.28-13.64	3.02-3.26	-	0.00-0.04
26	77.31-79.36	97.14-97.16	20.64-22.69	2.84-2.86	-	-
27	92.81-94.73	*	5.45-7.19	*	-	*
28	93.77-94.10	*	5.90-6.23	*	-	*
29	88.30-88.58	93.08-96.97	11.42-11.70	2.92-6.92	-	0.00-0.15
30	79.26-79.47	96.25-96.83	20.53-20.74	2.99-3.75	-	0.00 0.29
31	92.10-92.31	*	[illegible]60-7.75	*	0.97-0.30	*
32	74.04-74.74	96.56-96.93	25.26-25.96	3.07-3.38	-	0.00 0.06
33	93.37-93.83	96.26-96.48	6.17-6.63	3.16-3.222	-	0.30-1.57
34	92.97-92.65	96.69-96.80	7.35-7.73	2.90-2.92	-	0.30-0.39
35	81.15-81.55	96.36-96.38	18.85-18.45	3.62-3.64	-	-
36	92.30-92.58	97.11-97.20	7.42-7.70	2.80-2.89	-	-
37	80.10-80.25	87.22-87.57	19.75-19.90	12.43-12.78	-	-

38	76.13-80.51	96.90-97.01	19.49-23.87	2.99-3.10	-	-
39	82.25-82.39	96.25-96.45	17.61-17.75	3.55-3.75	-	-
40	89.13-89.98	93.90-96.79	10.02-10.87	2.81-6.10	-	0.00-0.40
41	85.10-86.41	*	13.59-14.89	*	0.00-0.41	*
42	77.04-77.06	96.38-96.81	22.83-22.85	3.19-3.62	0.11-0.11	-
43	94.80-95.73	96.02-97.06	4.27-5.20	2.81-3.82	-	0.13-0.15
44	86.66-87.38	91.22-92.10	12.85-13.34	7.90-8.78	-	-
45	92.40-93.48	*	6.52-7.60	*	-	*
46	86.34-88.76	*	11.24-13.66	*	-	*
47	88.28-89.01	*	10.99-11.72	*	-	*
48	93.44-93.79	*	6.21-6.56	*	-	*
49	92.13-92.89	*	7.05-7.53	*	0.00-0.36	*
50	94.46-95.39	96.31-96.73	4.61-5.54	3.17-3.58	0.10-0.11	
51	87.67-87.78	92.36-97.42	12.22-12.33	2.58-7.64	-	-
52	77.99-78.51	89.94-96.38	21.49-21.81	3.62-10.06	0.00-0.20	-
53	82.33-82.42	96.26-96.52	17.58-17.67	3.48-3.74	-	-
54	93.23-93.97	94.38-96.39	6.02-6.70	5.62-3.46	0.00-0.22	0.00-0.15
55	84.86-86.28	88.92-96.37	13.72-16.56	4.44-11.08	0.00-0.20	0.00-0.17
56	88.60-92.58	93.04-96.04	7.42-11.3	3.96-6.96	0.00-0.21	-
57	90.27-90.98	95.04-95.28	9.02-9.72	4.72-4.96	0.00-0.05	-

TABLE 51. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 25. Mesh 60.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam
1	11.09	29.77	0.090	0.034	917.28	967.50	0.073	234
2	4.34	30.95	0.230	0.032	812.80	968.70	0.169	244
3	13.37	*	0.075	*	930.39	*	0.099	290
4	2.87	25.49	0.348	0.039	741.87	962.25	0.311	305
5	3.66	14.55	0.273	0.069	785.32	842.12	0.075	279
6	8.61	9.90	0.116	0.101	895.93	908.27	0.053	263
7	5.04	19.95	0.198	0.050	834.40	952.27	0.061	392
8	4.88	27.09	0.205	0.037	830.00	964.40	0.167	377
9	11.85	21.73	0.084	0.046	922.21	956.00	0.187	303
10	10.67	29.58	0.064	0.034	940.01	967.30	0.210	421
11	3.67	22.58	0.272	0.044	785.66	957.60	0.105	445
12	12.97	22.26	0.077	0.045	928.41	957.00	0.105	408
13	2.45	11.63	0.408	0.086	710.40	920.80	0.115	472
14	12.14	*	0.082	*	923.88	*	0.079	426
15	11.78	30.06	0.085	0.033	920.81	967.90	0.165	329

16	11.81	33.72	0.085	0.030	921.91	971.20	0.169	284
17	13.06	*	0.077	*	928.90	*	0.104	375
18	13.10	22.20	0.076	0.045	929.08	956.90	0.075	350
19	12.10	*	0.082	*	924.02	*	0.102	386
20	6.81	*	0.147	*	871.90	*	0.149	361
21	5.41	30.23	0.185	0.033	844.00	967.98	0.090	247
22	15.17	25.63	0.066	0.039	938.17	962.45	0.107	181
23	14.01	*	0.071	*	933.37	*	0.105	223
24	4.63	18.11	0.216	0.055	822.26	947.68	0.132	249
25	4.61	31.04	0.156	0.032	865.00	968.79	0.122	344
26	3.65	34.09	0.274	0.029	784.90	971.50	0.134	299
27	14.70	*	0.068	*	936.30	*	0.093	236
28	15.29	*	0.065	*	938.60	*	0.147	320
29	7.65	22.30	0.131	0.045	884.40	957.08	0.167	298
30	3.85	29.72	0.260	0.034	793.62	967.45	0.170	296
31	12.04	*	0.083	*	923.29	*	0.109	271
32	2.90	29.86	0.345	0.034	743.90	967.59	0.142	369
33	14.70	30.21	0.068	0.033	936.30	967.96	0.138	293
34	12.12	33.25	0.083	0.030	923.50	968.86	0.059	329
35	4.36	26.55	0.229	0.038	813.50	963.70	0.234	311

36	12.16	34.09	0.082	0.029	924.00	971.50	0.093	388
37	4.04	6.96	0.248	0.144	801.72	874.33	0.130	294
38	3.43	31.79	0.292	0.032	774.32	969.50	0.384	352
39	4.65	26.40	0.215	0.038	823.20	963.50	0.185	256
40	8.57	21.38	0.117	0.047	895.51	955.32	0.147	312
41	6.01	*	0.166	*	857.44	*	0.102	409
42	3.37	28.33	0.297	0.035	771.35	965.90	0.125	199
43	20.10	28.72	0.050	0.035	952.60	966.35	0.071	311
44	6.73	10.99	0.149	0.091	870.60	916.60	0.129	254
45	13.16	*	0.076	*	929.40	*	0.139	319
46	6.74	*	0.148	*	870.80	*	0.100	310
47	7.74	*	0.129	*	885.60	*	0.275	214
48	14.53	*	0.069	*	935.60	*	0.210	259
49	12.97	*	0.077	*	928.40	*	0.156	300
50	19.00	28.56	0.053	0.035	950.00	966.17	0.156	321
51	7.14	21.32	0.140	0.047	877.21	955.20	0.157	358
52	3.61	15.26	0.277	0.066	782.85	938.50	0.094	434
53	4.67	26.40	0.214	0.038	823.72	963.50	0.191	560
54	14.79	19.65	0.068	0.051	936.66	951.58	0.360	687
55	5.73	17.01	0.175	0.059	851.47	944.48	0.336	668

56	8.84	18.42	0.113	0.054	898.38	948.50	0.269	357
57	9.81	19.66	0.102	0.051	907.49	951.60	0.062	392

TABLE 52. Electron probe analyses of native gold from Locality 25; average wt%. Mesh 120.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	87.70	97.22	12.31	2.78	0.00	0.00
2	80.28	*	19.28	*	0.44	*
3	80.85	89.04	18.72	10.55	0.43	0.42
4	88.19	94.32	10.76	4.06	1.06	1.62
5	82.74	93.43	16.77	6.28	0.50	0.30
6	85.74	91.04	13.48	7.67	0.80	1.29
7	88.16	93.74	10.87	5.44	0.98	0.83
8	81.61	94.15	16.68	5.13	0.72	1.71
9	86.27	92.29	13.00	6.78	0.73	0.94
10	85.29	*	13.73	*	0.98	*
11	87.50	*	11.79	*	0.71	*
12	86.70	*	12.58	*	0.71	*
13	87.44	*	11.71	*	0.86	*
14	83.83	*	15.16	*	1.02	*
15	85.78	*	13.41	*	0.81	*
16	84.68	95.42	14.67	3.13	0.66	1.45
17	86.70	95.03	12.60	3.67	0.71	1.30

TABLE 53. Electron probe analyses of native gold from Locality 25; ranges (wt%). Mesh 120.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	87.65-87.74	97.19-97.25	12.26-12.35	2.75-2.81	-	
2	78.41-81.52	*	18.20-21.20	*	0.27-0.67	*
3	80.46-81.24	88.81-89.27	18.29-19.15	10.36-10.73	0.39-0.47	0.37-0.46
4	88.10-88.27	93.53-95.11	10.62-10.90	4.05-4.07	1.00-1.11	0.84-2.40
5	82.20-83.28	91.78-95.08	16.13-17.40	4.58-7.98	0.40-0.59	0.24-0.35
6	85.24-86.24	90.03-92.05	13.07-13.88	6.71-8.63	0.70-0.89	1.24-1.34
7	86.65-89.66	93.70-93.78	9.08-12.65	5.37-5.50	0.69-1.26	0.72-0.93
8	80.49-82.73	93.82-94.47	14.92-18.44	4.81-5.45	1.07-2.35	0.71-0.73
9	85.13-87.41	91.49-93.08	11.65-14.35	5.97-7.58	0.52-0.94	0.93-0.95
10	85.12-85.37	*	12.48-14.23	*	0.65-1.14	*
11	86.80-88.09	*	11.24-12.37	*	0.63-0.83	*
12	86.46-86.94	*	12.29-12.97	*	0.32-1.25	*
13	86.09-88.78	*	10.54-12.88	*	0.68-1.04	*
14	83.60-84.05	*	14.63-15.69	*	0.71-1.32	*
15	85.14-86.17	*	12.95-14.22	*	0.65-1.01	*
16	83.62-85.73	95.20-95.64	13.58-15.76	2.93-3.32	0.62-0.69	1.43-1.47
17	85.01-88.38	94.86-95.20	11.22-13.98	3.58-3.76	0.40-1.01	1.22-1.38

TABLE 54. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 25. Mesh 120.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq diam
1	7.12	34.97	0.140	0.029	876.91	972.20	0.136	141
2	4.16	*	0.240	*	806.35	*	0.486	231
3	4.32	8.44	0.231	0.118	811.99	894.07	0.184	188
4	8.20	23.23	0.122	0.043	891.26	958.73	0.101	154
5	4.93	14.88	0.203	0.067	831.47	937.02	0.075	132
6	6.36	11.87	0.157	0.084	864.14	922.30	0.167	135
7	8.11	17.23	0.123	0.058	890.24	945.15	0.152	174
8	4.89	18.35	0.204	0.054	830.30	948.33	0.159	156
9	6.64	13.61	0.151	0.073	869.04	931.56	0.143	132
10	6.21	*	0.161	*	861.34	*	0.166	132
11	7.42	*	0.135	*	881.26	*	0.205	157
12	6.89	*	0.145	*	873.29	*	0.091	123
13	7.47	*	0.134	*	881.90	*	0.090	129
14	5.53	*	0.181	*	846.85	*	0.096	130
15	6.40	*	0.156	*	864.80	*	0.120	122

16	5.77	30.49	0.173	0.033	852.34	968.24	0.180	148
17	6.88	25.89	0.145	0.039	873.11	962.82	0.087	113

TABLE 55. Electron probe analyses of native gold from Locality 26; average wt%. Mesh 35.

Grain no.	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	78.63	96.23	21.37	3.77	0.00	0.01
2	95.30	95.64	4.63	4.34	0.07	0.02
3	89.36	94.96	10.64	4.95	0.00	0.08
4	88.37	89.90	11.61	10.10	0.03	0.01
5	91.36	94.36	8.64	5.58	0.01	0.06
6	78.45	79.53	21.44	20.47	0.01	0.00

TABLE 56. Electron probe analyses of native gold from Locality 26; ranges (wt%). Mesh 35.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	78.26-79.37	95.34-96.81	20.63-21.74	3.19-4.53	-	0.00-0.06
2	94.89-95.85	94.84-96.57	4.10-5.11	3.43-5.13	0.00-0.26	0.00-0.04
3	89.12-89.75	94.79-95.10	10.25-10.88	4.90-4.99	-	0.00-0.22
4	88.14-88.66	89.63-90.19	11.34-11.86	9.80-10.37	0.07-0.00	0.00-0.02
5	91.03-91.61	92.10-96.45	8.39-8.97	3.55-7.82	0.00-0.07	0.00-0.10
6	78.30-78.87	79.27-80.18	21.13-21.67	19.82-20.73	0.00-0.03	-

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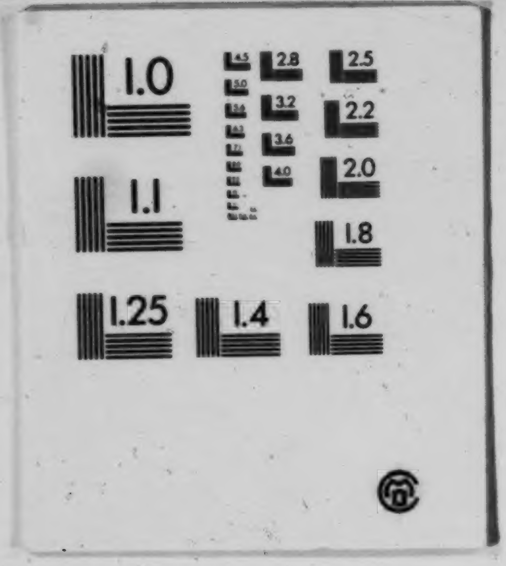
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4.5
5.0
5.6
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

TABLE 57. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 26. Mesh 35.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N.	Fineness R	Shape factor	Eq. diam.
1	3.68	25.53	0.272	0.039	786.30	962.30	0.150	637
2	20.58	22.04	0.049	0.045	953.67	956.59	0.072	558
3	8.40	19.18	0.119	0.052	893.60	950.46	0.049	470
4	7.61	8.90	0.131	0.112	883.88	899.00	0.081	531
5	10.57	16.91	0.095	0.059	913.60	944.17	0.084	633
6	3.66	3.89	0.273	0.257	785.36	795.30	0.108	592

TABLE 58. Electron probe analyses of native gold from Locality 26; average wt%. Mesh 60.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	93.83	*	6.13	*	0.05	*
2	91.47	*	8.50	*	0.03	*
3	92.08	*	7.79	*	0.14	*
4	84.72	96.72	15.24	3.19	0.04	0.09
5	92.91	*	7.03	*	0.06	*
6	88.11	*	11.86	*	0.03	*
7	92.53	96.78	7.41	3.21	0.05	0.01
8	92.86	96.60	7.12	3.40	0.03	0.00
9	85.18	97.04	14.82	2.96	0.00	0.00
10	93.23	*	6.71	*	0.06	0.00
11	88.17	91.59	11.81	8.40	0.02	0.02
12	86.70	*	13.29	*	0.01	*
13	88.28	*	11.72	*	0.00	*
14	91.29	97.00	8.67	3.00	0.04	0.00
15	84.18	96.54	15.82	3.45	0.00	0.00
16	92.55	*	7.45	*	0.00	*
17	93.27	94.93	6.68	5.00	0.07	0.07

18	79.37	92.63	20.63	7.37	0.00	0.00
19	93.54	95.48	6.46	4.32	0.00	0.02
20	90.28	95.43	9.73	4.56	0.00	0.01
21	85.03	96.30	14.97	3.70	0.00	0.00
22	77.10	*	22.90	*	0.00	*
23	88.67	96.42	11.33	3.58	0.00	0.00
24	91.31	*	8.69	*	0.00	*
25	79.56	82.43	20.50	17.58	0.00	0.00
26	91.44	96.77	8.56	3.23	0.00	0.00
27	93.24	*	6.75	*	0.01	*
28	91.45	*	8.41	*	0.14	*
29	83.51	97.04	16.43	2.89	0.07	0.07
30	92.73	96.66	7.24	3.34	0.03	0.00
31	89.10	91.64	10.90	8.16	0.00	0.21
32	66.85	85.30	33.15	14.70	0.00	0.00
33	81.16	*	18.84	*	0.00	0.00
34	93.73	*	6.27	*	0.00	0.00
35	92.91	*	6.97	*	0.11	0.00
36	83.64	*	16.36	*	0.00	*
37	93.96	*	6.04	*	0.00	*

38	80.94	95.54	9.06	4.46	0.00	0.00
39	72.21	95.96	7.79	4.04	0.00	0.00
40	91.42	96.50	8.58	3.50	0.00	0.00
41	81.14	96.35	18.86	3.66	0.00	0.00
42	90.74	96.45	9.26	3.55	0.00	0.00
43	91.62	96.21	8.38	3.79	0.00	0.00
44	88.85	*	11.15	*	0.00	*
45	79.97	95.89	20.04	4.12	0.00	0.00
46	89.49	96.28	10.52	3.72	0.00	0.00
47	89.83	*	10.17	*	0.00	0.00
48	86.39	90.89	13.62	9.12	0.00	0.00
49	91.20	95.68	8.80	4.32	0.00	0.00
50	68.99	96.48	31.01	3.52	0.00	0.00
51	92.59	96.14	7.41	3.86	0.00	0.00
52	91.58	95.54	8.42	4.47	0.00	0.00
53	90.18	96.64	9.77	3.36	0.05	0.00
54	90.82	96.28	9.18	3.72	0.00	0.00
55	83.42	96.00	16.45	3.77	0.02	0.25
56	82.99	93.85	16.98	5.97	0.03	0.18
57	91.06	95.04	8.94	4.96	0.00	0.00

58	85.80	96.27	14.20	3.58	0.00	0.16
59	86.30	94.24	13.70	5.76	0.00	0.00
60	91.02	96.22	8.39	3.78	0.05	0.00
61A	74.53	*	25.44	*	0.03	*
61B	92.00	*	7.96	*	0.04	*
61C	*	*	*	*	*	*
61D	82.97	*	16.91	*	0.12	*
61E	79.66	*	20.14	*	0.19	*
62	81.80	95.53	18.20	4.47	0.01	0.00
63	89.61	*	10.36	*	0.02	0.02

TABLE 59. Electron probe analyses of native gold from Locality 26; ranges (wt%). Mesh 60.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	93.39-94.38	*	5.62-6.48	*	0.00-0.14	*
2	90.97-92.39	*	7.61-8.97	*	0.00-0.06	*
3	91.98-92.17	*	7.75-7.82	*	0.08-0.20	*
4	84.57-84.87	96.60-96.81	15.05-15.43	3.16-3.22	0.00-0.08	0.00-0.18
5	92.46-93.34	*	6.50-7.53	*	0.00-0.16	*
6	87.63-88.59	*	11.35-12.37	*	0.00-0.06	*
7	92.39-92.67	96.73-96.80	7.33-7.50	3.17-3.25	0.00-0.11	0.00-0.02
8	92.75-92.97	96.50-96.70	7.03-7.20	3.30-3.50	0.00-0.05	-
9	85.06-85.29	96.96-97.12	14.71-14.94	2.88-3.04	-	-
10	93.10-93.35	*	6.51-6.90	*	0.00-0.13	*
11	87.37-88.93	91.07-92.10	11.07-12.57	7.87-8.92	0.00-0.06	0.02-0.03
12	85.67-88.04	*	11.94-14.33	*	0.00-0.01	*
13	88.27-88.28	*	11.72-11.73	*	-	*
14	91.06-91.52	96.88-97.12	8.40-8.94	2.88-3.12	0.00-0.08	-
15	81.37-86.99	96.48-96.59	13.01-18.63	3.38-3.52	-	0.00-0.03
16	92.00-92.71	*	7.30-7.80	*	-	*
17	92.55-93.99	94.53-95.67	5.91-7.45	4.26-5.38	0.06-0.09	0.07-0.08

18	79.09-79.65	91.76-93.50	20.35-20.91	6.50-8.24	–	
19	93.44-93.64	95.30-96.02	6.36-6.56	3.95-4.68	–	0.02-0.03
20	90.17-90.38	95.30-95.55	9.62-9.83	4.44-4.68	–	0.01-0.02
21	84.99-85.07	95.48-97.12	14.93-15.00	2.88-4.52	–	–
22	76.55-78.08	*	21.92-23.45	*	–	*
23	88.60-88.74	95.02-97.14	11.26-11.40	2.86-4.98	–	–
24	91.14-91.43	*	8.57-8.86	*	–	*
25	79.45-79.69	82.35-82.50	20.31-20.55	17.50-17.65	–	–
26	91.39-91.49	96.75-96.79	8.51-8.61	3.21-3.25	–	
27	93.15-93.32	*	6.68-6.82	*	0.00-0.03	*
28	90.90-92.45	*	7.34-9.10	*	0.00-0.22	*
29	83.48-83.53	96.99-97.09	16.36-16.49	2.86-2.91	0.03-0.11	0.00-0.15
30	92.73-92.74	96.50-96.81	7.20-7.27	3.19-3.50	0.00-0.06	
31	89.04-89.15	91.06-92.21	10.85-10.96	7.61-8.70	–	0.18-0.24
32	67.07-66.62	85.10-85.49	32.93-33.38	14.51-14.90	–	–
33	80.94-81.45	*	18.55-19.06	*	–	*
34	93.66-93.87	*	6.13-6.34	*	–	*
35	91.68-93.87	*	6.13-6.34	*	–	*
36	83.58-83.70	*	5.62-6.48	*	0.00-0.14	*
37	93.70-94.67	*	5.33-6.30	*	–	*

38	80.58-81.18	93.87-96.43	18.82-19.42	3.57-6.13	–	–
39	72.17-72.55	95.67-96.29	27.45-27.83	3.71-4.33	–	–
40	91.10-91.61	96.42-96.58	8.39-8.90	3.42-3.58	–	
41	80.81-81.47	96.14-96.55	18.53-19.19	3.45-3.86	–	–
42	90.58-90.90	96.07-96.42	9.10-9.42	3.58-3.93	–	–
43	91.23-92.12	95.87-96.55	6.58-8.77	3.45-4.13	–	–
44	88.42-89.30	*	10.70-11.58	*	–	–
45	79.52-80.41	95.02-96.25	19.59-20.48	3.75-4.98	–	–
46	88.07-90.74	96.02-96.48	9.26-11.93	3.52-3.98	–	–
47	86.30-90.95	*	9.05-13.70	*	–	–
48	85.39-87.38	90.73-91.04	12.62-14.61	8.96-9.27	–	
49	90.85-91.63	94.57-96.21	8.37-9.15	3.79-5.43	–	
50	68.77-69.38	96.15-96.91	30.62-31.23	3.09-3.85	–	
51	92.35-92.74	95.98-96.27	7.26-7.65	3.73-4.02	–	
52	91.25-92.02	95.23-95.84	7.98-8.75	4.16-4.77	–	
53	89.79-90.63	96.41-97.00	9.37-10.07	3.00-3.59	0.00-0.35	
54	89.99-91.89	96.12-96.48	8.11-10.01	3.52-3.88	–	
55	83.00-83.95	95.80-96.19	16.05-17.00	3.72-3.81	0.00-0.20	0.00-0.49
56	82.92-83.13	88.13-96.65	16.87-17.08	3.35-11.87	0.00-0.15	0.00-1.10
57	90.65-91.52	94.16-95.73	8.47-9.34	4.27-5.84	–	

58	85.69-85.91	95.52-97.13	14.09-14.31	2.87-4.48	–	0.00-0.41
59	85.77-86.70	90.25-96.73	13.30-14.23	3.27-9.75	–	
60	90.65-91.31	95.91-96.58	8.62-9.35	3.42-4.09	0.00-0.30	
61A	73.05-77.37	*	22.63-26.95	*	0.00-0.08	*
61B	90.31-95.31	*	4.69-9.62	*	0.00-0.12	*
61C	*	*	*	*	*	*
61D	89.93-83.01	*	16.84-16.96	*	0.10-0.15	*
61E	79.51-79.91	*	19.93-20.29	*	0.16-0.21	*
62	79.00-88.69	94.33-96.40	11.30-21.00	3.60-5.67	0.00-0.02	
63	88.90-90.61	*	9.31-11.10	*	0.00-0.09	*

TABLE 60. Au/Ag. Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 26. Mesh 60.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	15.31	*	0.065	*	938.68	*	0.086	305
2	10.76	*	0.093	*	914.97	*	0.101	308
3	11.82	*	0.085	*	922.00	*	0.112	261
4	5.56	30.32	0.180	0.033	847.54	968.07	0.233	466
5	13.22	*	0.076	*	929.66	*	0.088	327
6	7.43	*	0.135	*	881.36	*	0.162	326
7	12.49	30.15	0.080	0.033	925.86	967.90	0.333	330
8	13.05	28.41	0.077	0.035	928.83	966.00	0.091	338
9	5.75	32.78	0.174	0.031	851.80	970.40	0.088	251
10	13.89	*	0.072	*	932.86	*	0.072	285
11	7.47	*	0.134	*	881.88	915.99	0.120	460
12	6.52	*	0.153	*	867.09	*	0.135	345
13	7.53	*	0.133	*	882.80	*	0.110	325
14	10.53	32.33	0.095	0.031	913.27	970.00	0.135	468
15	5.32	27.98	0.188	0.036	841.80	965.50	0.113	186

16	12.42	*	0.081	*	925.50	*	0.062	237
17	13.96	18.99	0.072	0.053	933.17	989.58	0.131	303
18	3.85	12.57	0.260	0.080	793.70	926.30	0.072	316
19	14.48	22.10	0.069	0.045	935.40	956.71	0.115	209
20	9.28	20.93	0.108	0.048	886.70	954.40	0.134	285
21	5.68	26.03	0.176	0.038	850.30	963.00	0.144	298
22	3.37	*	0.297	*	771.00	*	0.261	213
23	7.83	26.93	0.128	0.037	886.70	964.20	0.157	298
24	10.51	*	0.095	*	913.10	*	0.049	370
25	3.88	4.69	0.258	0.213	795.12	824.22	0.082	296
26	10.68	29.96	0.094	0.033	914.40	967.70	0.096	415
27	13.81	*	0.072	*	932.49	*	0.092	244
28	10.87	*	0.092	*	915.78	*	0.060	324
29	5.08	33.58	0.197	0.030	835.60	971.08	0.230	242
30	12.81	28.94	0.078	0.035	927.58	966.60	0.077	254
31	8.17	11.23	0.122	0.089	891.00	918.24	0.190	293
32	2.02	5.80	0.495	0.172	668.50	853.00	0.169	317
33	4.31	*	0.232	*	811.60	*	0.154	518
34	14.95	*	0.067	*	937.30	*	0.085	360
35	13.33	*	0.075	*	930.22	*	0.108	290

36	5.11	*	0.196	*	836.40	*	0.061	320
37	15.56	*	0.064	*	939.60	*	0.117	259
38	8.93	21.42	0.112	0.047	809.40	955.40	0.076	331
39	9.27	21.52	0.108	0.046	722.10	959.60	0.070	386
40	10.66	27.57	0.094	0.036	914.20	965.00	0.100	276
41	4.30	26.33	0.233	0.038	811.40	963.50	0.079	276
42	9.80	27.17	0.102	0.037	907.40	964.50	0.113	266
43	10.93	25.39	0.091	0.039	916.20	962.10	0.099	348
44	7.97	*	0.125	*	888.50	*	0.143	340
45	3.99	23.27	0.251	0.043	799.70	958.90	0.105	345
46	8.51	25.88	0.118	0.039	894.90	962.80	0.066	350
47	8.83	*	0.113	*	898.30	*	0.114	354
48	6.34	9.97	0.158	0.100	863.90	908.90	0.050	276
49	10.36	22.15	0.097	0.045	912.00	956.80	0.139	369
50	2.22	27.41	0.450	0.036	689.90	964.80	0.080	335
51	12.50	24.91	0.080	0.040	925.90	961.40	0.078	408
52	10.88	21.37	0.092	0.047	915.80	955.40	0.094	347
53	9.23	28.76	0.108	0.035	902.25	966.40	0.146	371
54	9.09	25.88	0.197	0.039	908.20	962.80	0.117	359
55	5.07	25.46	0.200	0.039	835.29	962.21	0.113	351

56	4.89	15.72	0.204	0.064	830.15	940.19	0.138	377
57	10.19	26.89	0.098	0.037	910.60	950.40	0.147	384
58	6.04	26.89	0.166	0.037	858.00	964.14	0.194	481
59	6.30	16.36	0.159	0.061	863.00	942.40	*	*
60	10.19	25.46	0.098	0.039	910.65	962.20	0.087	373
61A	2.93	*	0.341	*	745.52	*	0.653	577
61B	11.56	*	0.087	*	920.37	*	*	*
61C	*	*	*	*	*	*	*	*
61D	4.91	*	0.204	*	830.70	*	*	*
61E	3.96	*	0.253	*	798.20	*	*	*
62	4.49	21.37	0.223	0.047	818.00	955.30	0.385	504
63	8.65	*	0.116	*	896.37	*	0.034	296

TABLE 61. Electron probe analyses of native gold from Locality 26; average wt%. Mesh 120

Grain no.	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	89.41	96.40	10.54	3.58	0.05	0.02
2	92.46	95.57	7.52	4.43	0.03	0.00
3	92.70	93.27	7.21	6.73	0.10	0.00
4	79.49	*	20.50	*	0.02	*
5	90.98	96.48	8.83	3.47	0.19	0.05
6	82.05	96.12	17.92	3.80	0.04	0.07
7	90.65	96.14	9.34	3.74	0.02	0.12
8	89.45	93.87	10.29	5.90	0.26	0.24
9	93.52	*	6.45	*	0.02	*
10	89.16	95.22	10.74	4.67	0.11	0.11
11	83.64	96.37	16.36	3.57	0.00	0.07
12	91.68	96.34	8.12	3.66	0.21	0.00
13	92.05	94.08	7.68	5.92	0.00	0.00
14	90.16	93.14	9.92	6.86	0.00	0.00
15	92.25	94.31	7.75	5.70	0.00	0.00
16	78.05	95.93	21.33	4.07	0.00	0.00
17	92.40	96.55	7.58	3.45	0.00	0.00

18	88.85	92.37	11.15	7.63	0.00	0.00
19	89.29	96.49	10.71	3.51	0.00	0.00
20	91.93	92.85	8.07	7.15	0.00	0.00
21	87.01	95.96	12.99	4.04	0.00	0.00
22	92.58	92.48	7.41	7.52	0.00	0.00
23	79.92	79.04	20.09	20.96	0.00	0.00
24	91.94	96.00	8.07	4.00	0.00	0.00
25	89.93	94.12	10.07	5.88	0.00	0.00
26A	96.42	95.93	3.59	4.07	0.00	0.00
26B	95.97	96.08	4.03	3.92	0.00	0.00
27	84.29	95.76	15.71	4.24	0.00	0.00
28	83.03	96.50	16.97	3.50	0.00	0.00
29	88.10	95.42	11.90	4.58	0.00	0.00
30	89.24	89.86	10.76	10.14	0.00	0.00
31	87.26	96.33	12.74	12.74	0.00	0.00
32	83.11	96.28	16.90	3.73	0.00	0.00
33	83.80	94.95	16.20	5.05	0.00	0.00
34	91.04	96.25	8.96	3.75	0.00	0.00
35	88.78	96.15	11.22	3.85	0.00	0.00
36	93.14	95.77	6.86	4.23	0.00	0.00

37	91.17	93.61	8.83	6.39	0.00	0.00
38	89.33	96.12	10.57	3.52	0.10	0.29
39	78.97	95.64	20.95	3.47	0.08	0.89
40	87.66	89.98	12.06	9.92	0.25	0.10
41	92.50	95.73	7.24	4.25	0.27	0.03
42	87.33	88.37*	12.33	11.27*	0.34	0.36
43	92.37	95.73	7.33	3.76	0.31	0.51
44	87.97	90.32*	11.90	9.21*	0.15	0.47
45	90.44	95.59	8.87	3.64	0.69	0.77
46	55.59	93.77	44.08	5.61	0.33	0.81
47	84.30	96.25	15.25	3.41	0.49	0.34
48	78.21	94.91	21.37	3.84	0.43	1.25
49	90.17	*	8.59	*	1.25	*
50	64.10	71.63	34.82	27.84	1.08	0.54
51	93.01	96.46	6.85	3.28	0.14	0.26
52	91.83	95.64	7.92	4.02	0.24	0.35
53	91.74	95.69	7.58	3.71	0.60	0.69
54	84.70	96.07	14.90	3.78	0.39	0.15

TABLE 62. Electron probe analyses of native gold from Locality 26; ranges (wt%). Mesh 120.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	89.17-89.99	96.33-96.48	10.01-10.83	3.52-3.61	0.00-0.22	0.00-0.08
2	92.06-93.55	95.01-96.29	6.31-7.94	3.71-4.99	0.00-0.15	-
3	92.65-92.72	93.10-93.46	7.13-7.28	6.54-6.90	0.00-0.15	-
4	79.26-79.62	*	20.38-20.72	*	0.00-0.02	*
5	90.75-91.19	96.32-96.63	8.53-9.14	3.37-3.57	0.10-0.29	0.00-0.18
6	81.64-82.79	95.96-96.21	17.21-18.28	3.77-3.85	0.00-0.11	0.00-0.18
7	90.50-90.85	95.92-96.36	9.09-9.50	3.45-4.03	0.00-0.07	0.05-0.19
8	88.89-90.01	93.80-93.93	9.47-11.11	5.88-5.91	0.00-0.052	0.19-0.29
9	93.18-93.89	*	6.11-6.82	*	0.00-0.08	*
10	88.87-89.44	94.74-95.92	10.54-10.93	4.06-5.05	0.02-0.20	0.02-0.22
11	83.30-83.98	96.14-96.67	16.02-16.70	3.41-3.84	-	0.00-0.18
12	91.58-91.77	96.01-96.67	8.04-8.19	3.99-3.99	0.19-0.23	-
13	91.75-92.29	93.43-94.60	6.08-8.25	5.08-6.57	-	-
14	89.51-89.91	93.08-93.20	6.80-6.92	9.49-10.09	-	-
15	91.90-92.73	92.73-94.51	7.27-8.10	5.90-7.27	-	-
16	76.80-79.48	95.80-96.15	20.52-22.52	3.85-4.20	-	-
17	84.46-85.32	96.40-96.53	14.68-15.54	3.47-3.60	-	-

18	87.03-89.52	87.30-98.33	10.27-12.70	1.67-10.76	-	-
19	89.17-89.49	96.42-96.52	10.51-10.83	3.48-3.58	-	-
20	91.66-92.16	92.70-93.10	7.84-8.34	6.90-7.30	-	-
21	86.80-87.34	94.74-96.66	12.66-13.20	3.34-5.26	-	-
22	92.28-92.83	92.10-92.68	7.17-7.72	7.32-7.90	-	-
23	79.69-80.14	78.32-79.48	19.86-20.31	20.52-21.68	-	-
24	91.85-92.02	95.30-96.60	7.98-8.15	3.40-4.70	-	-
25	89.74-90.17	91.48-96.18	9.83-10.26	3.82-8.52	-	-
26A	96.31-96.52	95.40-96.37	3.48-3.69	3.63-4.60	-	-
26B	95.81-96.13	95.79-96.37	3.87-4.19	3.63 4.21	-	-
27	83.77-84.81	94.35-96.48	15.19-16.23	3.52-5.65	-	-
28	82.80-83.26	96.40-96.71	16.74-17.20	3.29-3.60	-	-
29	87.66-88.45	94.64-96.20	11.55-12.34	3.80-5.36	-	-
30	87.71-90.07	89.79-89.93	9.93-12.29	10.07-10.21	-	-
31	87.17-87.35	96.09-96.58	12.65-12.83	3.42-3.91	-	-
32	82.70-83.44	96.02-96.59	16.56-17.30	3.44-3.98	-	-
33	83.00-84.30	92.99-96.13	15.70-17.00	3.87-7.01	-	-
34	90.50-91.40	95.85-96.67	8.60-9.50	3.33-4.15	-	-
35	88.69-88.86	95.95-96.48	11.14-11.31	3.52-4.05	-	-
36	93.06-93.26	95.04-96.26	6.74-6.94	3.74-4.96	-	-

37	90.95-91.43	93.53-93.71	8.57-9.05	6.29-6.47	-	-
38	88.97-89.58	94.92-96.78	10.42-10.75	3.22-3.94	0.00-0.28	0.00-1.14
39	78.70-79.16	94.96-96.16	20.84-21.08	3.01-3.85	0.00-0.23	0.29-1.21
40	87.42-87.86	88.63-91.11	11.56-12.49	8.68-11.37	0.04-0.80	0.00-0.21
41	91.92-93.81	94.05-96.53	5.95-7.83	3.44-5.88	0.23-0.34	0.00-0.07
42	87.02-87.63	*	11.58-12.87	*	0.00-0.79	*
43	92.09-92.62	92.26-94.08	6.80-7.55	3.20-5.29	0.03-0.58	0.30-0.64
44	87.56-88.57	*	11.43-12.11	*	0.00-0.35	*
45	89.52-90.80	95.18-96.09	7.79-9.53	3.24-3.95	0.17-1.41	0.67-0.87
46	53.62-57.16	91.37-95.28	42.52-46.13	4.29-8.63	0.23-0.47	0.00-1.10
47	83.88-84.65	*	14.86-15.96	*	0.16-1.01	*
48	77.76-78.66	94.48-95.49	21.16-21.57	3.55-4.04	0.18-0.67	1.48-1.69
49	90.32-90.01	*	8.39-8.79	*	1.20-1.29	*
50	63.65-64.80	71.21-72.04	34.39-35.06	27.32-28.36	0.81-1.33	0.43-0.64
51	92.47-93.47	96.42-96.50	6.53-7.20	3.20-3.35	0.00-0.33	0.15-0.37
52	91.35-92.28	95.59-96.68	7.53-8.34	3.99-4.04	0.02-0.56	0.28-0.42
53	91.46-92.02	95.59-95.68	7.18-7.97	3.43-4.16	0.57-0.80	0.36-0.82
54	83.82-85.49	96.03-96.11	14.41-15.71	3.71-3.85	0.09-0.62	0.12-0.18

TABLE 63. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 26. Mesh 120.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam
1	8.48	26.93	0.118	0.037	894.55	964.19	0.277	266
2	12.30	21.57	0.081	0.046	924.79	955.70	0.204	247
3	12.86	13.86	0.078	0.072	927.84	932.70	0.202	252
4	3.88	*	0.258	*	794.98	*	0.110	283
5	10.30	27.80	0.097	0.036	911.53	965.28	0.176	237
6	4.58	25.29	0.218	0.040	820.75	961.97	0.290	252
7	9.71	25.71	0.103	0.039	906.59	962.56	0.317	238
8	8.69	15.91	0.115	0.063	896.83	940.86	0.149	247
9	14.50	*	0.069	*	935.48	*	0.130	251
10	8.30	20.39	0.120	0.049	892.49	953.25	0.153	261
11	5.11	26.99	0.196	0.037	836.40	964.28	0.158	280
12	11.29	26.32	0.089	0.038	918.64	963.40	0.127	255
13	11.98	15.89	0.083	0.063	922.98	940.80	0.103	242
14	9.09	13.58	0.110	0.074	900.88	931.40	0.129	248
15	11.90	16.55	0.084	0.060	922.50	943.01	0.406	201

16	3.66	23.57	0.273	0.042	785.37	959.30	0.127	202
17	5.64	27.25	0.177	0.037	849.40	964.60	0.181	190
18	7.97	12.11	0.125	0.083	888.50	923.70	0.142	228
19	8.34	27.49	0.120	0.036	892.90	964.90	0.138	247
20	11.39	12.97	0.088	0.077	919.30	928.50	0.195	266
21	6.70	23.75	0.149	0.042	870.10	959.60	0.322	245
22	12.49	12.30	0.080	0.081	925.89	924.80	0.217	203
23	3.98	3.77	0.251	0.265	799.12	790.40	0.098	234
24	11.39	24.00	0.088	0.042	919.31	960.00	0.189	271
25	8.93	16.01	0.112	0.062	899.30	941.20	0.132	253
26A	26.86	23.57	0.037	0.042	964.10	959.30	0.170	274
26B	23.81	24.51	0.042	0.041	959.70	960.80	-	-
27	5.37	22.58	0.186	0.044	842.90	959.30	0.206	302
28	4.89	27.57	0.204	0.036	959.70	960.80	0.132	249
29	7.40	20.83	0.135	0.048	842.90	957.60	0.140	225
30	8.29	8.86	0.121	0.113	830.30	965.00	0.141	229
31	6.85	26.18	0.146	0.038	881.00	954.20	0.203	251
32	4.29	25.81	0.203	0.039	892.40	898.60	0.236	286
33	5.17	18.80	0.193	0.053	872.60	963.20	0.164	323
34	10.16	25.67	0.098	0.039	831.02	962.70	0.180	241

35	7.91	24.97	0.126	0.040	887.80	961.50	0.226	234
36	13.58	22.64	0.074	0.044	931.40	957.70	0.162	209
37	10.33	14.65	0.097	0.068	911.70	936.10	0.112	240
38	8.45	27.31	0.118	0.037	894.19	964.67	0.151	219
39	3.77	27.56	0.265	0.036	790.33	964.99	0.141	242
40	7.27	9.07	0.138	0.110	879.06	900.70	0.236	285
41	12.78	22.52	0.078	0.044	927.41	957.49	0.211	210
42	7.08	7.84	0.141	0.128	876.28	886.89	0.166	258
43	12.60	25.46	0.079	0.039	926.48	962.21	0.202	289
44	7.39	9.81	0.135	0.102	880.85	907.47	0.234	189
45	10.20	26.26	0.098	0.038	910.28	963.32	0.141	229
46	1.26	16.71	0.794	0.060	557.74	943.55	0.216	276
47	5.53	28.23	0.181	0.035	846.81	965.78	0.168	273
48	3.66	24.72	0.273	0.040	785.40	961.11	0.119	257
49	10.50	*	0.095	*	913.02	*	0.107	166
50	1.84	2.57	0.543	0.389	648.00	720.12	0.209	211
51	13.58	29.41	0.074	0.034	931.40	967.11	0.182	197
52	11.59	23.79	0.086	0.042	920.60	959.66	0.102	227
53	12.10	25.79	0.083	0.039	923.68	962.68	0.202	195
54	5.68	25.42	0.176	0.039	850.40	962.14	0.129	268

TABLE 64. Electron probe analyses of native gold from Locality 26; average wt%. Mesh 230.

Grain no.	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	92.40	96.55	7.58	3.45	0.01	0.00
2	67.70	89.15	32.25	11.85	0.06	0.00
3	85.00	95.40	15.00	4.60	0.00	0.00
4	66.00	88.11	33.96	11.88	0.04	0.01
5	89.90	95.81	10.10	4.19	0.00	0.00
6	68.50	88.20	31.50	11.77	0.00	0.02
7	92.16	97.12	7.80	2.86	0.03	0.01
8	86.11	93.14	13.89	6.86	0.00	0.00
9	91.12	96.05	8.88	3.95	0.00	0.00
10	82.10	90.51	17.87	9.48	0.10	0.02
11	85.41	92.03	14.55	7.95	0.03	0.04
12	67.20	89.18	32.75	10.80	0.03	0.01
13	86.00	96.10	14.00	3.89	0.00	0.02
14	93.12	94.15	6.85	5.85	0.02	0.01
15	87.22	93.70	12.70	6.30	0.10	0.00
16	88.17	91.44	11.83	8.56	0.00	0.00
17	81.40	92.70	18.60	7.30	0.00	0.00

18	67.77	86.90	32.18	13.08	0.06	0.02
19	85.55	93.22	14.45	6.78	0.00	0.00
20	87.73	93.50	12.27	6.49	0.00	0.01
21	86.40	95.88	13.60	4.10	0.00	0.02
22	70.18	86.80	29.80	13.18	0.01	0.01
23	90.03	96.09	9.97	3.91	0.00	0.00

TABLE 65. Electron probe analyses of native gold from Locality 26; ranges (wt%). Mesh 230.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	92.31-92.50	96.50-96.62	7.50-7.63	3.38-3.58	0.00-0.04	–
2	67.39-67.89	89.00-89.41	32.08-32.38	11.76-11.94	0.00-0.12	–
3	84.89-85.17	95.21-95.61	14.15-15.44	4.50-4.71	–	–
4	65.82-66.17	88.02-88.17	33.85-34.08	11.79-11.92	0.00-0.16	0.00-0.12
5	89.45-90.17	94.92-96.08	9.84-10.56	3.92-5.09	–	–
6	68.38-68.61	88.04-88.33	31.63-31.37	11.67-11.87	–	–
7	92.03-92.25	97.05-97.27	7.17-8.41	2.80-2.95	0.00-0.11	0.00-0.05
8	85.99-86.30	93.02-93.21	13.80-13.97	6.75-6.94	–	–
9	91.04-91.27	95.89-96.18	8.63-8.99	3.80-4.13	–	–
10	81.95-82.33	90.33-90.60	17.76-17.91	9.36-9.61	0.01-0.15	0.00-0.05
11	85.10-85.81	91.88-92.41	14.15-14.87	7.55-8.08	0.02-0.06	0.00-0.05
12	67.00-67.31	89.04-89.25	32.63-32.94	10.70-10.92	0.05-0.01	0.00-0.03
13	85.90-86.08	92.02-96.14	13.88-14.11	3.79-3.95	–	-0.00-0.05
14	93.04-93.19	94.05-94.19	6.77-6.94	5.78-5.93	0.00-0.07	0.00-0.03
15	87.12-87.30	93.58-93.84	12.55-12.88	6.10-6.43	0.05-0.18	–
16	88.07-88.23	91.05-91.55	11.76-11.94	8.45-8.94	–	–
17	81.22-81.53	92.15-92.91	18.47-18.78	7.08-7.84	–	–

18	67.68-67.84	86.80-87.01	32.05-32.27	13.00-13.89	0.00-0.17	0.00-0.10
19	85.40-85.68	93.06-93.35	14.33-14.61	6.66-6.93	–	–
20	87.60-87.91	93.12-93.66	12.08-12.40	6.30-6.82	–	0.00-0.08
21	86.18-86.53	95.63-96.04	13.47-13.81	4.35-3.93	–	0.00-0.05
22	70.00-70.44	86.70-86.92	29.53-29.97	13.05-13.27	0.00-0.01	0.00-0.05
23	89.29-90.15	96.00-96.18	9.85-10.11	3.82-4.00	–	

TABLE 66. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 26. Mesh 230.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	12.19	27.99	0.082	0.036	924.18	965.50	0.129	131
2	2.10	7.52	0.476	0.133	677.34	891.50	0.150	110
3	5.67	20.74	0.176	0.048	850.00	954.00	0.179	122
4	1.94	7.42	0.515	0.135	660.26	881.19	0.200	101
5	8.90	22.87	0.112	0.044	899.00	958.10	0.210	99
6	2.17	7.49	0.460	0.133	685.00	882.26	0.159	140
7	11.82	33.96	0.085	0.029	921.97	971.39	0.220	126
8	6.20	13.58	0.161	0.074	861.10	931.40	0.130	109
9	10.26	24.32	0.097	0.041	911.20	960.50	0.172	102
10	4.59	9.55	0.218	0.105	821.25	915.19	0.184	89
11	5.87	11.58	0.170	0.086	854.44	920.48	0.188	101
12	2.05	8.26	0.487	0.121	672.34	891.98	0.128	140
13	6.14	24.70	0.163	0.040	860.00	961.10	0.133	138
14	13.59	16.09	0.074	0.062	931.48	941.50	0.159	120
15	6.87	14.87	0.146	0.067	872.90	937.00	0.194	106

16	7.45	10.68	0.134	0.094	881.70	914.40	0.210	790
17	4.38	12.70	0.229	0.079	814.00	927.00	0.195	112
18	2.11	6.64	0.475	0.151	678.04	869.17	0.170	117
19	5.92	13.75	0.169	0.073	855.50	932.20	0.128	133
20	7.15	14.41	0.140	0.069	877.30	935.09	0.208	100
21	6.35	23.39	0.157	0.043	864.00	958.99	0.203	98
22	2.36	6.59	0.425	0.152	701.94	868.17	0.308	139
23	9.03	24.58	0.111	0.041	900.30	960.90	0.180	107

TABLE 67. Electron probe analyses of native gold from Locality 27; average wt%. Mesh 60.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	90.96	96.41	9.04	3.59	0.00	0.00
2	88.51	95.28	11.49	4.72	0.00	0.00
3	92.41	96.02	7.59	3.98	0.00	0.00
4	61.28	86.11	38.72	13.89	0.00	0.00
5	96.20	89.11	3.80	10.89	0.00	0.00
6	90.10	96.57	9.90	3.43	0.00	0.00
7	80.88	95.00	19.12	5.00	0.00	0.00
8	89.24	96.12	10.76	3.88	0.00	0.00
9	86.63	96.24	13.38	3.76	0.00	0.00
10	92.20	96.33	7.80	3.68	0.00	0.00
11	55.79	63.53	44.21	36.47	0.00	0.00
12	92.65	*	7.35	*	0.00	0.00
13	85.00	96.34	15.00	3.67	0.00	0.00
14	78.30	96.38	21.70	3.62	0.00	0.00
15	91.05	95.69	8.96	4.32	0.00	0.00
16	92.14	96.43	7.86	3.57	0.00	0.00
17	79.05	94.72	20.96	5.29	0.00	0.00

18	87.00	93.43	13.00	6.57	0.00	0.00
19	87.54	96.31	12.46	3.69	0.00	0.00
20	85.95	89.79	14.05	10.21	0.00	0.00
21	89.44	96.01	10.56	3.99	0.00	0.00
22	92.70	*	7.30	*	0.00	*
23	86.87	*	13.13	*	0.00	*
24	90.30	*	9.70	*	0.00	*
25	87.13	94.73	12.88	5.27	0.00	0.00
26	90.27	93.22	9.25	6.78	0.00	0.00
27	80.52	87.42	19.48	12.58	0.00	0.00
28	87.49	94.87	12.51	5.13	0.00	0.00
29	87.28	*	12.72	*	0.00	*
30	88.03	96.11	11.98	3.89	0.00	0.00
31A	75.56	91.51	22.44	8.49	0.00	0.00
31B	90.25	*	9.75	*	0.00	*
32	87.64	94.48	12.36	5.52	0.00	0.00

TABLE 68. Electron probe analyses of native gold from Locality 27; ranges (wt%). Mesh 60.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	90.57-92.01	96.13-96.65	7.99-9.43	3.35-3.87	–	–
2	88.37-88.79	94.23-96.01	11.21-11.63	3.99-5.77	–	–
3	92.10-92.83	96.00-96.04	7.17-7.90	3.96-4.00	–	–
4	60.11-62.69	85.49-86.81	37.31-39.89	13.19-14.51	–	–
5	88.54-89.47	96.05-96.37	10.53-11.46	3.63-3.95	–	–
6	98.78-90.34	96.48-96.72	9.66-10.22	3.28-3.52	–	–
7	80.62-81.17	92.79-96.18	18.83-19.38	3.82-7.21	–	–
8	88.01-89.85	95.62-96.86	10.15-11.09	3.14-4.38	–	–
9	84.22-89.03	96.17-96.31	10.97-15.78	3.69-3.83	–	–
10	91.69-93.05	96.00-96.65	6.95-8.31	3.35-4.00	–	–
11	54.43-56.88	63.14-63.82	43.12-45.57	36.18-36.86	–	–
12	92.23-93.75	*	6.25-7.77	*	–	*
13	84.08-86.74	96.26-96.41	13.26-15.92	3.59-3.74	–	–
14	75.95-82.35	96.33-96.42	17.65-24.05	3.58-3.67	–	–
15	89.90-91.68	94.34-96.28	8.32-10.10	3.72-5.66	–	–
16	91.93-92.32	96.41-96.47	7.68-8.07	3.53-3.59	–	–
17	78.83-79.51	93.17-96.17	20.49-21.17	3.83-6.83	–	–

18	86.91-87.13	93.34-93.56	12.87-13.09	6.44-6.66	-	-
19	85.84-90.90	96.26-96.37	9.10-14.16	3.63-3.74	-	-
20	85.73-86.19	89.59-90.02	13.81-14.27	9.98-10.41	-	-
21	88.44-89.15	95.29-96.47	8.29-11.56	3.53-4.71	-	-
22	92.40-92.94	*	7.06-7.60	*	-	*
23	86.28-87.36	*	12.64-13.72	*	-	*
24	86.79-95.93	*	4.07-13.21	*	-	*
25	86.73-87.39	94.40-95.10	12.61-13.27	4.90-5.60	-	
26	89.48-90.75	92.77-93.75	19.36-19.57	12.01-13.07	-	-
27	80.43-80.64	86.93-87.99	19.36-19.57	12.01-13.07	-	-
28	87.39-87.62	92.62-96.49	12.38-12.61	3.51-7.38	-	-
29	86.76-87.75	*	12.25-13.24	*	-	*
30	87.12-88.13	95.61-96.75	11.87-12.08	3.25-4.39	-	
31A	75.32-75.80	84.18-95.75	24.20-24.68	4.25-15.82	-	-
31B	88.11-92.18	*	7.82-11.89	*	-	*
32	87.33-88.21	94.42-94.52	11.79-12.67	5.48-5.58	-	-

TABLE 69. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 27. Mesh 60.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	10.06	26.86	0.099	0.037	909.60	964.10	0.072	453
2	7.70	20.19	0.130	0.050	885.10	952.80	0.123	351
3	12.18	24.13	0.082	0.041	924.10	960.20	0.179	352
4	1.58	6.20	0.633	0.161	612.80	861.10	0.181	346
5	25.32	8.18	0.039	0.122	962.00	891.10	0.085	224
6	9.10	28.15	0.110	0.036	901.00	965.70	0.221	435
7	4.23	19.00	0.236	0.053	808.80	950.00	0.121	405
8	6.18	24.77	0.162	0.040	892.40	961.20	0.099	256
9	6.47	35.60	0.155	0.039	866.30	962.40	0.097	294
10	11.82	26.18	0.085	0.038	922.00	963.30	0.217	395
11	1.26	1.74	0.794	0.575	557.90	635.30	0.094	360
12	12.61	*	0.079	*	926.50	*	0.069	367
13	5.67	26.25	0.176	0.038	850.00	963.40	0.267	479
14	3.61	26.62	0.277	0.038	783.00	963.80	0.217	653
15	10.16	22.15	0.098	0.045	910.50	956.90	0.108	218

16	11.72	27.011	0.085	0.037	921.40	964.30	0.144	375
17	3.77	17.91	0.265	0.056	790.50	947.20	0.169	446
18	6.69	14.22	0.149	0.070	870.00	934.30	0.165	400
19	7.03	26.10	0.142	0.038	875.40	963.10	0.120	433
20	6.12	8.79	0.163	0.114	859.50	897.90	0.152	526
21	8.47	24.06	0.118	0.042	894.40	960.10	0.193	587
22	12.70	*	0.079	*	927.00	*	0.101	382
23	6.62	*	0.151	*	868.70	*	0.045	273
24	9.31	*	0.107	*	903.00	*	0.236	504
25	6.76	17.98	0.148	0.056	871.30	947.30	0.283	545
26	9.76	13.75	0.102	0.073	907.05	932.20	0.149	401
27	4.13	6.95	0.242	0.144	805.20	874.20	0.262	448
28	6.99	18.50	0.143	0.054	874.90	948.70	0.212	503
29	6.86	*	0.146	*	872.80	*	0.102	415
30	7.35	24.71	0.136	0.040	880.30	961.10	0.255	463
31	3.09	10.79	0.324	0.093	755.60	915.10	0.184	499
32	9.26	*	0.108	*	902.50	*	*	*
33	7.09	17.12	0.141	0.058	876.40	944.80	0.158	509

TABLE 70. Electron probe analyses of native gold from Locality 27; average wt%. Mesh 120.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	89.31	96.04	10.65	3.96	0.03	0.00
2	72.72	93.03	27.28	6.94	0.00	0.03
3	78.53	92.66	21.45	7.29	0.02	0.05
4	92.77	*	7.19	*	0.05	*
5	81.28	92.35	18.72	7.63	0.00	0.02
6	92.49	96.44	7.49	3.54	0.02	0.02
7	73.67	96.90	26.34	3.11	0.00	0.00
8	63.60	96.78	35.35	3.15	0.04	0.07
9	64.49	95.95	35.50	4.01	0.00	0.04
10	86.27	*	13.68	*	0.06	*
11	71.94	93.01	28.01	6.99	0.04	0.00

TABLE 71. Electron probe analyses of native gold from Locality 27; ranges (wt%). Mesh 120.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	85.93-92.63	95.30-96.55	7.25-14.07	3.45-4.70	0.00-0.13	0.00-0.01
2	71.61-73.46	91.82-96.08	26.54-28.39	3.92-8.11	-	0.00-0.08
3	76.97-81.08	92.51-92.95	18.92-23.01	7.05-7.42	0.00-0.14	0.00-0.17
4	91.29-96.48	*	3.52-8.50	*	0.00-0.21	*
5	80.11-81.82	91.55-94.84	18.18-19.89	5.09-8.45	-	0.00-0.09
6	92.10-93.04	96.13-96.91	6.95-7.90	3.09-3.86	0.00-0.06	0.00-0.09
7	73.62-73.71	96.65-97.14	26.29-26.38	2.86-3.35	-	
8	64.03-65.21	96.48-96.97	34.79-35.97	2.93-3.39	0.00-0.13	0.00-0.20
9	64.01-65.44	95.44-96.58	34.56-35.99	3.30-3.56	0.00-0.01	0.00-0.12
10	85.67-87.27	*	12.73-14.35	*	0.00-0.17	*
11	71.50-72.86	90.00-94.60	27.14-28.47	5.40-10.00	0.00-0.26	

TABLE 72. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 27. Mesh 120.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	8.39	24.25	0.119	0.041	893.46	960.40	0.244	452
2	2.67	13.40	0.375	0.075	727.20	930.57	0.183	307
3	3.66	12.71	0.273	0.079	785.46	927.06	0.243	350
4	12.90	*	0.078	*	928.16	*	0.165	248
5	4.34	12.10	0.230	0.083	812.80	923.68	0.221	281
6	12.35	27.24	0.081	0.037	925.09	964.59	0.266	261
7	2.80	31.16	0.357	0.032	736.70	969.00	0.448	341
8	1.80	30.72	0.556	0.033	656.01	968.48	0.213	279
9	1.82	23.93	0.549	0.042	644.90	959.88	0.201	253
10	6.31	*	0.158	*	863.13	*	0.176	237
11	2.57	13.31	0.389	0.075	719.69	930.10	0.873	272

TABLE 73. Electron probe analyses of native gold from Locality. 28; average wt%. Mesh 120.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	87.71	96.55	12.23	3.27	0.07	0.19
2A	86.80	96.41	13.16	3.52	0.04	0.07
2B	81.40	95.29	18.58	4.40	0.03	0.31
3	91.21	96.56	8.68	3.17	0.11	0.08
4	91.60	94.74	8.33	5.25	0.08	0.02
5	93.49	*	6.48	*	0.04	*
6	90.27	96.27	9.72	3.65	0.01	0.08
7	79.25	87.16	20.71	12.84	0.04	0.00
8	81.43	83.35*	18.53	16.63*	0.05	0.02
9	92.30	95.33	7.66	4.49	0.04	0.18
10	92.20	96.20	7.78	3.80	0.03	0.00
11	88.25	94.57	11.65	5.43	0.09	0.00
12	95.02	*	4.89	*	0.09	*
13	58.66	96.21	41.34	3.79	0.00	0.00
14	90.48	96.17	41.34	3.81	0.03	0.03
15	92.17	92.27	7.74	7.70	0.09	0.03
16A	93.43	*	6.49	*	0.08	*

16B	89.32	*	10.68	*	0.00	*
17	91.88	96.87	8.08	2.98	0.03	0.15
18	*	92.83	*	7.17	*	0.00
19	77.32	96.41	22.67	3.52	0.02	0.07
20A	92.67	96.57	7.32	3.43	0.01	0.00
20B	92.13	92.19	7.79	7.76	0.09	0.05
21A	82.70	*	17.30	*	0.00	*
21B	80.42	96.48	19.55	3.49	0.04	0.03
21C	89.96	*	10.02	*	0.02	*
21D	80.81	96.52	19.17	3.46	0.02	0.03
22	92.50	96.03	7.37	3.98	0.13	0.00
23	88.92	96.45	10.93	3.50	0.16	0.04
24	93.37	*	6.63	*	0.00	*
25	91.36	*	5.64	*	0.00	*
26	91.58	96.31	8.42	3.69	0.00	0.00
27	79.78	88.57	20.15	11.43	0.06	0.00
28A	92.67	93.32	7.33	6.69	0.00	0.00
28B	93.42	94.37	6.58	5.63	0.00	0.00
28C	96.33	vugs	3.67	vugs	0.00	0.00
29	84.09	94.22	15.92	5.79	0.00	0.00

16B	89.32	*	10.68	*	0.00	*
17	91.88	96.87	8.08	2.98	0.03	0.15
18	*	92.83	*	7.17	*	0.00
19	77.32	96.41	22.67	3.52	0.02	0.07
20A	92.67	96.57	7.32	3.43	0.01	0.00
20B	92.13	92.19	7.79	7.76	0.09	0.05
21A	82.70	*	17.30	*	0.00	*
21B	80.42	96.48	19.55	3.49	0.04	0.03
21C	89.96	*	10.02	*	0.02	*
21D	80.81	96.52	19.17	3.46	0.02	0.03
22	92.50	96.03	7.37	3.98	0.13	0.00
23	88.92	96.45	10.93	3.50	0.16	0.04
24	93.37	*	6.63	*	0.00	*
25	91.36	*	5.64	*	0.00	*
26	91.58	96.31	8.42	3.69	0.00	0.00
27	79.78	88.57	20.15	11.43	0.06	0.00
28A	92.67	93.32	7.33	6.69	0.00	0.00
28B	93.42	94.37	6.58	5.63	0.00	0.00
28C	96.33	vugs	3.67	vugs	0.00	0.00
29	84.09	94.22	15.92	5.79	0.00	0.00

30	78.45	96.01	21.23	3.99	0.32	0.00
31	81.32	86.39	18.42	13.61	0.27	0.00
32	91.38	*	8.62	*	0.00	*
33	81.43	88.11	18.58	11.89	0.00	0.00
34	92.40	94.52	7.60	5.48	0.00	0.00
35	91.97	96.26	8.03	3.75	0.00	0.00
36	88.41	92.54	11.59	7.46	0.00	0.00
37	80.61	81.52	19.29	18.48	0.10	0.00
38	92.43	96.53	7.57	3.47	0.00	0.00
39	77.39	82.22	22.07	17.66	0.54	0.13

TABLE 74. Electron probe analyses of native gold from Locality 28; ranges (wt%). Mesh 120.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	87.09-88.42	96.70-96.40	11.58-12.91	3.44-3.10	0.00-0.26	0.17-0.20
2A	85.95-92.42	96.38-96.44	7.52-14.05	3.48-3.56	0.00-0.11	0.00-0.14
2B	81.21-81.50	95.48-95.10	18.44-18.79	4.30-4.50	0.00-0.08	0.22-0.40
3	90.95-91.44	96.20-96.91	8.41-9.05	2.94-3.80	0.00-0.24	0.00-0.15
4	91.35-91.76	93.45-96.31	8.18-8.56	3.69-6.55	0.00-0.14	0.00-0.05
5	93.32-93.83	*	6.17-6.65	*	0.00-0.12	*
6	88.53-93.56	96.01-96.45	6.44-11.47	3.47-3.93	0.00-0.04	0.00-0.19
7	78.91-79.55	86.88-87.44	20.40-21.09	12.56-13.12	0.00-0.10	-
8	80.87-81.96	82.92-83.78	18.04-19.00	16.22-17.03	0.00-0.14	0.00-0.04
9	92.09-92.63	95.25-95.41	7.37-7.91	4.32-4.65	0.00-0.11	0.09-0.27
10	91.96-92.43	95.95-96.40	7.57-7.98	3.60-4.05	0.00-0.05	
11	87.56-88.85	94.52-94.62	11.15-12.26	5.38-5.48	0.00-0.17	
12	94.39-95.85	*	4.06-5.44	*	0.00-0.17	*
13	58.48-58.84	96.20-96.23	41.15-41.52	3.77-3.80	0.00-0.01	-
14	90.40-90.56	95.51-96.77	9.40-9.59	3.23-4.49	0.01-0.04	0.00-0.10
15	91.88-92.46	92.16-92.41	7.54-7.94	7.58-7.76	0.00-0.18	0.00-0.09
16A	92.61-93.90	*	6.11-7.29	*	0.00-0.26	*

16B	89.26-89.39	*	10.61-10.72	*	0.00-0.02	*
17	91.58-92.21	96.73-97.01	7.79-8.31	2.80-3.16	0.00-0.10	0.10-0.19
18	n/a	92.55-93.11	n/a	6.89-7.45	n/a	
19	76.87-77.76	96.03-96.69	22.20-23.13	3.17-3.97	0.00-0.04	0.00-0.14
20A	91.81-93.49	96.39-96.75	6.51-8.19	3.25-3.61	0.00-0.04	
20B	92.12-92.13	91.96-92.32	7.70-7.88	7.61-7.96	0.00-0.18	0.00-0.08
21A	82.55-82.86	*	17.14-17.45	*	–	*
21B	80.17-80.67	96.42-96.57	19.32-19.78	3.43-3.58	0.01-0.06	0.00-0.08
21C	89.71-90.14	*	9.87-10.29	*	0.00-0.09	*
21D	80.71-80.91	96.40-96.62	12.29-19.05	3.29-3.60	0.00-0.04	0.00-0.09
22	92.48-92.52	94.48-96.71	7.28-7.46	3.29-5.52	0.06-0.20	
23	88.79-89.04	96.28-96.71	10.79-11.06	3.29-3.72	0.15-0.17	0.00-0.13
24	92.36-94.01	*	5.99-7.64	*	–	*
25	94.27-94.50	*	5.50-5.73	*	–	*
26	91.52-91.64	96.27-96.33	8.36-8.48	3.67-3.73	–	
27	79.36-80.32	88.01-89.62	19.63-20.50	10.38-11.99	0.00-0.14	
28A	92.57-92.79	93.22-93.41	7.21-7.43	6.59-6.78	–	
28B	93.08-93.76	94.10-94.64	6.24-6.92	5.36-5.90	–	
28C	96.30-96.36	*v	3.64-3.70	*v	–	
29	84.01-84.16	91.73-96.70	15.84-15.99	3.20-8.27	–	–

30	78.21-78.61	95.55-96.45	21.10-21.48	3.55-4.45	0.28-0.36	
31	81.20-81.43	86.26-86.52	18.29-18.55	13.48-13.74	0.25-0.28	
32	91.31-91.45	*	8.55-8.69	*	–	*
33	81.40-81.45	87.81-88.35	18.55-18.60	11.65-12.19	–	
34	92.24-92.56	94.40-94.61	7.43-7.76	5.39-5.60	–	
35	91.86-92.04	96.04-96.53	7.96-8.14	3.47-3.96	–	
36	88.27-88.51	91.65-93.57	11.49-11.73	6.43-8.35	–	
37	80.57-80.64	81.43-81.61	19.15-19.43	18.39-18.57	0.00-0.20	
38	92.38-92.51	96.38-96.65	7.49-7.62	3.35-3.62	–	
39	76.95-77.98	82.15-82.28	21.82-22.31	17.62-17.69	0.20-0.74	0.10-0.15

TABLE 75. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 28. Mesh 120.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	7.17	29.53	0.139	0.034	877.63	967.24	0.189	204
2A	6.60	27.39	0.152	0.037	868.35	964.78	0.437	237
2B	4.38	21.66	0.228	0.046	814.16	955.86	"	"
3	10.51	30.46	0.095	0.033	913.10	968.21	0.172	200
4	11.00	18.05	0.091	0.055	916.64	947.49	0.081	146
5	14.43	*	0.069	*	935.18	*	0.092	153
6	9.29	26.38	0.108	0.038	902.79	963.47	0.115	153
7	3.83	6.79	0.261	0.147	792.82	871.60	0.115	210
8	4.39	5.01	0.228	0.200	814.63	833.67	0.169	224
9	12.05	21.23	0.083	0.047	923.37	955.02	0.090	185
10	11.85	25.32	0.084	0.039	922.18	962.00	0.173	227
11	7.58	17.42	0.132	0.057	883.38	945.70	0.124	164
12	19.43	*	0.051	*	951.06	*	0.194	148
13	1.42	25.39	0.704	0.039	586.60	962.10	0.227	200
14	9.53	25.24	0.105	0.040	904.98	961.89	0.188	159

15	11.91	11.98	0.084	0.083	922.53	922.98	0.236	178
16A	14.40	*	0.069	*	935.05	*	0.783	322
16B	8.36	*	0.120	*	893.20	*	*	*
17	11.37	32.51	0.088	0.031	919.17	970.16	0.129	194
18	?	12.95	?	0.077	?	928.30	0.162	205
19	3.41	27.39	0.293	0.037	773.28	964.78	0.164	174
20A	11.83	11.88	0.085	0.084	922.04	922.36	0.279	261
20B	12.66	28.15	0.079	0.036	926.79	965.70	*	*
21A	4.78	*	0.209	*	827.00	*	0.281	289
21B	4.11	27.64	0.243	0.036	804.44	965.09	*	*
21C	8.98	*	0.111	*	899.78	*	*	*
21D	4.22	27.90	0.237	0.036	808.26	965.39	*	*
22	12.55	24.13	0.080	0.041	926.20	960.20	0.215	279
23	8.14	27.56	0.123	0.036	890.54	964.98	0.128	239
24	14.08	*	0.071	*	933.70	*	0.099	174
25	16.73	*	0.060	*	943.60	*	0.113	154
26	10.88	26.10	0.092	0.038	915.80	963.10	0.096	184
27	3.96	7.75	0.253	0.129	798.36	885.70	0.292	198
28A	14.20	16.76	0.070	0.060	934.20	943.70	0.372	312
28B	12.64	13.95	0.079	0.072	926.70	933.31	*	*

28C	26.25	*	0.038	*	963.30	*	*	*
29	5.28	16.27	0.189	0.061	840.82	942.11	0.176	237
30	3.70	24.06	0.270	0.042	787.02	960.10	0.142	238
31	4.42	6.35	0.226	0.157	815.32	863.90	0.135	183
32	10.60	*	0.094	*	913.80	*	0.156	214
33	4.38	7.11	0.228	0.135	814.22	881.10	0.087	220
34	12.16	17.25	0.082	0.058	924.00	945.20	0.573	324
35	11.45	25.67	0.087	0.039	919.70	962.50	0.100	155
36	7.63	12.40	0.131	0.081	884.10	925.40	0.118	160
37	4.18	4.41	0.239	0.227	806.91	815.20	0.105	167
38	12.21	27.82	0.082	0.036	924.30	965.30	0.125	164
39	3.51	4.66	0.285	0.215	778.10	823.19	0.863	219

TABLE 76. Electron probe analyses of native gold from Locality 33; average wt%. Mesh 230.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	87.40	96.27	12.60	3.73	0.00	0.00
2	89.57	98.30	10.43	1.64	0.00	0.06
3	84.73	97.00	15.28	3.00	0.00	0.00
4	71.22	85.38	28.68	14.70	0.10	0.00
5	85.35	95.00	14.60	5.00	0.01	0.00
6	81.50	86.65	18.43	13.35	0.10	0.00
7	95.50	*	4.43	*	0.06	*
8	83.33	*	16.65	*	0.03	*
9	87.80	93.10	12.12	6.90	0.10	0.00
10	95.42	*	4.69	*	0.00	0.00
11	77.24	83.95	22.74	16.05	0.00	0.00
12	91.40	97.31	8.60	2.30	0.00	0.00

TABLE 77. Electron probe analyses of native gold from Locality 33; ranges (wt%). Mesh 230.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	86.20-89.00	95.40-97.30	11.00-13.80	2.70-4.60	-	-
2	87.70-90.80	96.80-99.80	9.20-12.30	0.20-3.10	-	0.00-0.20
3	83.40-87.00	96.70-97.30	13.00-16.60	2.70-3.20	-	0.00-0.10
4	69.40-73.50	84.80-86.10	26.50-30.60	13.90-15.20	0.00-0.40	
5	85.00-85.80	94.30-96.00	14.10-15.00	4.00-5.70	0.00-0.10	-
6	81.20-81.90	86.20-87.10	18.00-18.70	12.90-13.80	0.00-0.10	0.00-0.10
7	95.30-95.70	*	4.20-4.70	*	0.00-0.10	*
8	83.00-83.80	*	16.20-17.00	*	0.00-0.10	*
9	86.40-88.50	92.10-94.20	11.50-13.60	5.80-7.90	0.00-0.20	-
10	95.00-95.80	*	4.30-5.00	*	0.00-0.10	*
11	71.30-80.60	83.80-84.10	19.40-28.70	15.90-16.20	0.00-0.10	
12	91.20-91.60	95.40-99.90	8.40-8.80	0.10-4.60	-	

TABLE 78. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 33. Mesh 230.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	6.94	25.81	0.144	0.039	874.00	962.70	0.270	89
2	8.59	59.94	0.116	0.017	895.70	983.59	0.295	76
3	5.55	32.33	0.180	0.031	847.30	970.00	0.217	96
4	2.48	5.80	0.403	0.172	712.20	853.00	0.242	96
5	5.84	19.00	0.171	0.053	853.00	950.00	0.278	87
6	4.42	6.49	0.226	0.154	815.57	866.50	0.510	97
7	21.56	*	0.046	*	955.67	*	0.215	90
8	5.00	*	0.200	*	833.47	*	0.270	92
9	7.24	13.49	0.138	0.074	878.70	931.00	0.423	110
10	20.65	*	0.048	*	954.20	*	0.161	84
11	3.40	5.23	0.294	0.191	772.40	839.50	0.157	85
12	10.63	42.31	0.094	0.024	914.00	973.10	0.194	78

TABLE 79. Electron probe analyses of native gold from Locality 35; average wt%. Mesh 120.

Grain no	Au% N	Au% R	Ag% N	Ag% R	Cu% N	Cu% R
1	92.90	94.91	6.97	5.07	0.13	0.02
2	76.03	97.07	23.67	2.93	0.03	0.00
3	73.41	*	26.54	*	0.05	*
4	92.56	96.99	7.41	3.01	0.04	0.00
5	88.35	89.50	11.55	10.50	0.11	0.00
6	76.71	96.28	23.26	3.58	0.04	0.14
7	93.84	96.93	6.06	3.04	0.11	0.03
8	91.32	*	8.66	*	0.02	*
9	89.81	96.37	10.10	3.63	0.00	0.00
10	89.18	*	10.72	*	0.10	*
11	76.66	96.21	23.34	3.79	0.00	0.00
12	84.25	*	15.64	*	0.11	*
13	85.30	*	14.55	*	0.15	*

TABLE 80. Electron probe analyses of native gold from Locality 35; ranges (wt%). Mesh 120.

Grain no	Range Au N	Range Au R	Range Ag N	RangeAg R	Range Cu N	Range Cu R
1	92,41–93.86	94.72–95.04	6.09–7.36	4.96–5.23	0.00–0.26	0.00–0.05
2	76.01–76.55	96.99–97.14	23.45–23.99	2.86–3.01	0.00–0.08	–
3	72.98–73.91	*	25.93–27.02	*	0.00–0.25	*
4	91.98–93.15	96.88–97.09	6.85–8.02	2.91–3.12	0.00–0.14	–
5	88.04–88.50	89.00–90.00	11.35–11.84	10.00–11.00	0.00–0.24	–
6	76.52–76.89	96.03–96.79	23.05–23.47	3.07–3.89	0.01–0.07	0.08–0.20
7	93.59–94.09	96.70–97.16	5.88–6.23	2.84–3.30	0.03–0.19	0.00–0.10
8	91.25–91.38	*	8.56–8.75	*	0.00–0.09	*
9	89.06–90.55	95.37–97.03	9.45–10.94	2.97–4.63	–	–
10	88.91–89.45	*	10.34–11.09	*	0.00–0.21	*
11	76.52–76.85	96.12–96.30	23.15–23.48	3.70–3.88	–	–
12	83.88–84.72	*	15.53–16.08	*	0.00–0.47	*
13	84.98–85.50	*	14.17–14.91	*	0.00–0.33	*

TABLE 81. Au/Ag, Ag/Au ratios, fineness, Corey shape factor and equivalent diameter of individual gold grains from Locality 35. Mesh 120.

Grain no	Au/Ag N	Au/Ag R	Ag/Au N	Ag/Au R	Fineness N	Fineness R	Shape factor	Eq. diam.
1	13.33	18.72	0.075	0.053	930.21	949.29	0.309	299
2	3.21	33.13	0.312	0.030	762.29	970.70	0.421	203
3	2.77	*	0.361	*	734.47	*	0.280	215
4	12.49	32.22	0.080	0.031	925.88	969.90	0.237	234
5	7.65	8.52	0.131	0.117	884.38	895.00	0.266	282
6	3.30	26.89	0.303	0.037	767.25	964.15	0.245	159
7	15.49	31.88	0.065	0.031	939.34	969.59	0.108	230
8	10.55	*	0.095	*	913.38	*	0.118	175
9	8.89	26.55	0.112	0.038	898.91	963.70	0.286	263
10	8.32	*	0.120	*	892.69	*	0.673	441
11	3.28	25.39	0.305	0.039	766.60	962.10	0.226	244
12	5.39	*	0.186	*	843.43	*	0.399	467
13	5.86	*	0.171	*	854.28	*	0.280	232

TABLE 82. Ranges of Corey factors and equivalent diameters for size-classified gold; North Saskatchewan River, Alberta.

Mesh	Corey Factors	Equiv. diam.	Number of grains
+35	0.048 ---> 0.155	470 - 640	6
+60	0.035 ---> 0.400	200 - 550	233
+120	0.070 ---> 0.350	120 - 320	137
+230	0.280 ---> 0.130	80 - 150	34

TABLE 83. Ranges of Corey factors and equivalent diameters for size-classified gold; Athabasca River, Alberta.

Mesh	Corey Factors	Equiv. diam.	Number of grains
+120	0.370 ---> 0.455	100 - 140	8
+230	0.055 ---> 0.550	65 - 150	58
-230	0.180 ---> 0.310 and 0.520 ---> 0.580	45 - 80	20

TABLE 84. Production of gold in Alberta from 1887 to 1981.

Year	Ounces	Kilograms
1887	102	3.173
1888	58	1.804
1889	967	30.081
1890	193	6.004
1891	266	8.275
1892	508	15.803
1893	466	14.496
1894	726	22.584
1895	2419	75.249
1896	2661	82.777
1897	2419	75.249
1898	1209	37.609
1899	726	22.584
1900	242	7.528
1901	726	22.584
1902	484	15.056
1903	48	1.493
1904	24	0.747
1905	121	3.764
1906	39	1.213
1907	33	1.027
1908	50	1.555
1909	25	0.778
1910	89	2.769
1911	10	0.311
1912	73	2.271
1913	0	0.000
1914	48	1.493

1915	195	6.066
1916	82	2.551
1917	0	0.000
1918	27	0.840
1919	24	0.747
1920	0	0.000
1921	49	1.524
1922	0	0.000
1923	0	0.000
1924	0	0.000
1925	0	0.000
1926	0	0.000
1927	42	1.307
1928	68	2.115
1929	5	0.156
1930	0	0.000
1931	195	6.066
1932	83	2.582
1933	324	10.390
1934	393	12.225
1935	150	4.666
1936	109	3.390
1937	46	1.431
1938	305	9.488
1939	359	11.168
1940	215	6.688
1941	215	6.688
1942	34	1.058
1943	21	0.653
1944	51	1.586

1945	7	0.218
1946	110	3.422
1947	78	2.426
1948	78	2.426
1949	0	0.000
1950	0	0.000
1951	0	0.000
1952	0	0.000
1953	65	2.022
1954	199	6.190
1955	214	6.657
1956	119	3.702
1957	416	1.294
1958	282	8.772
1959	200	6.222
1960	191	5.942
1961	171	5.319
1962	186	5.786
1963	132	4.106
1964	200	6.222
1965	200	6.222
1966	182	5.662
1967	146	4.542
1968	146	4.542
1969	133	4.137
1970	152	4.728
1971	79	2.457
1972	3	0.093
1973	175	5.444
1974	97	3.017

1975	246	7.652
1976	166	5.164
1977	66	2.053
1978	1116	34.716
1979	161	5.008
1980	4276	133.016
1981	3890	121.008

TABLE 85. Price of gold during the period 1887-1981

Year	Price($US)
1887	20.67
1888	20.67
1889	20.67
1890	20.67
1891	20.67
1892	20.67
1893	20.67
1894	20.67
1895	20.67
1896	20.67
1897	20.67
1898	20.67
1899	20.67
1900	20.67
1901	20.67
1902	20.67
1903	20.67
1904	20.67
1905	20.67
1906	20.67
1907	20.67
1908	20.67
1909	20.67
1910	20.67

1911	20.67
1912	20.67
1913	20.67
1914	20.67
1915	20.67
1916	20.67
1917	20.67
1918	20.67
1919	20.67
1920	20.67
1921	20.67
1922	20.67
1923	20.67
1924	20.67
1925	20.67
1926	20.67
1927	20.67
1928	20.67
1929	20.67
1930	20.67
1931	20.67
1932	20.67
1933	25.56
1934	34.95
1935	35.00
1936	35.00

1937	35.00
1938	35.00
1939	35.00
1940	35.00
1941	35.00
1942	35.00
1943	35.00
1944	35.00
1945	35.00
1946	35.00
1947	35.00
1948	35.00
1949	35.00
1950	35.00
1951	35.00
1952	35.00
1953	35.00
1954	35.00
1955	35.00
1956	35.00
1957	35.00
1958	35.00
1958	35.00
1959	35.00
1960	35.00
1961	35.00

1962	35.00
1963	35.00
1964	35.00
1965	35.00
1966	35.00
1967	35.00
1968	39.26
1969	41.51
1970	36.41
1971	41.25
1972	58.60
1973	97.81
1974	159.74
1975	161.49
1976	125.32
1977	148.31
1978	193.55
1979	307.50
1980	612.38
1981	460.00

TABLE 86. Composition (wt.%) of 10 platinum grains from the North Saskatchewan River, Alberta.

Sample	Pt	Fe	Cu	Rh
P1	90.170	8.150	0.178	1.502
P2	88.254	5.988	1.705	4.053
P3	89.006	4.928	1.960	4.107
P4	90.182	8.239	0.192	1.387
P5	89.232	4.890	1.841	4.037
P6	90.116	8.045	0.319	1.519
P7	90.135	8.148	0.238	1.479
P8	88.583	5.547	1.789	4.081
P9	90.348	7.972	0.233	1.448
P10	88.824	5.429	1.751	3.997